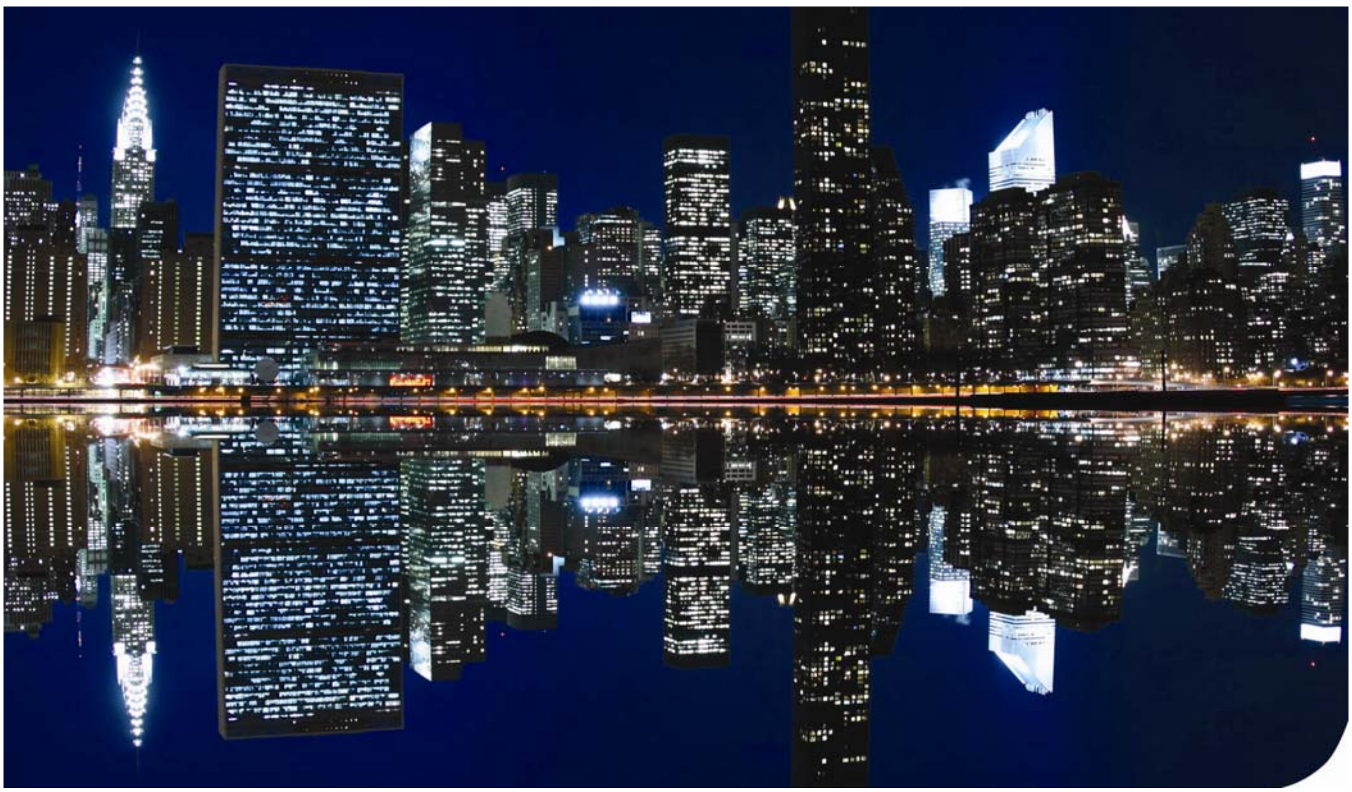
EnergyWise^{SM} Initial 2009/2010 Winter Load Impact Report

Progress Energy Carolinas



Raleigh, North Carolina, December 28, 2010

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1. Executive Summary

This report presents the initial load impact estimates for the 2009/2010 EnergyWise winter season based on the first of two planned M&V efforts. At the time of this initial M&V effort, the EnergyWise program was in its infancy and the number of participants enrolled in the program was low. Additional M&V effort is warranted to confirm the results of this initial effort.

This section provides a brief summary of the findings described in this report.

The central objective of this document is to describe the 2009/2010 performance and expected future performance of Progress Energy Carolina's winter EnergyWise program.

EnergyWise is a direct load control program that has the capability to reduce load at times of peak electricity demand and thereby defer the need for additional peaking capacity resources. The North Carolina Utilities Commission approved the program on October 14, 2008.

The winter program is offered in PEC's Western region only, and it consists of load control of central heat pump auxiliary strip heat and electric water heaters.

The methodology employed in the load impacts measurement and verification (M&V) of the EnergyWise winter 2009/2010 season included the following elements:

- Load Data Collection
- System Load and Temperature Data Analysis for the M&V Event Plan
- Load Data Preparation
- Load Data Modeling for 2009/2010 estimates: kW and kWh savings and snapback by hour for each M&V event conducted, at the participant level
- Weather Data Analysis for load impact projections
- Load Impact Projections for different temperature conditions and control strategies

1.1 Winter 2009/2010 Load Impact Estimates

At the beginning of the 2009/2010 winter season there were 204 water heaters and 130 strip heaters enrolled in the EnergyWise program. Because of the small number of program participants at that time, PEC and KEMA attempted to recruit all program participants into the M&V sample. The final sample size upon which the following results are based included 79 water heaters and 73 central heat pump auxiliary strip heaters.

Additional details regarding sample design, weather data, load data and model specifications can be found in the appendices to this report.

There were seven direct load control events included in the 2009/2010 winter M&V effort. All of these events ran between 7 and 9 AM.

The direct load control of central heat pump auxiliary strip heating consisted of 50 percent run time cycling, that is, the strip heating was allowed to run fifteen minutes out of every half hour. This level of cycling proved to be very mild as it achieved statistically significant load reductions in only four of the seven events conducted.

Figure 1-1 presents the average baseline load and the average actual event day load for the auxiliary strip heating measure over the seven EnergyWise events conducted in the winter of 2009/2010. The average strip heat load reduction during event hours was 0.3 kW. The figure illustrates that there was little to no snapback following the control event.

The direct load control of electric water heating consisted of 100 percent run time cycling – water heating was entirely interrupted for the two event hours. Figure 1-2 presents the average baseline and average actual event day load for water heating over the seven EnergyWise events conducted in the winter of 2009/2010. The average water heater load reduction during event hours was 0.4 kW. This load reduction was immediately followed by very large snapback, of 0.6 kW on average.

Figure 1-1
Auxiliary Strip Heat Baseline Average (from Model) Vs Event Day Average (from M&V Sample)

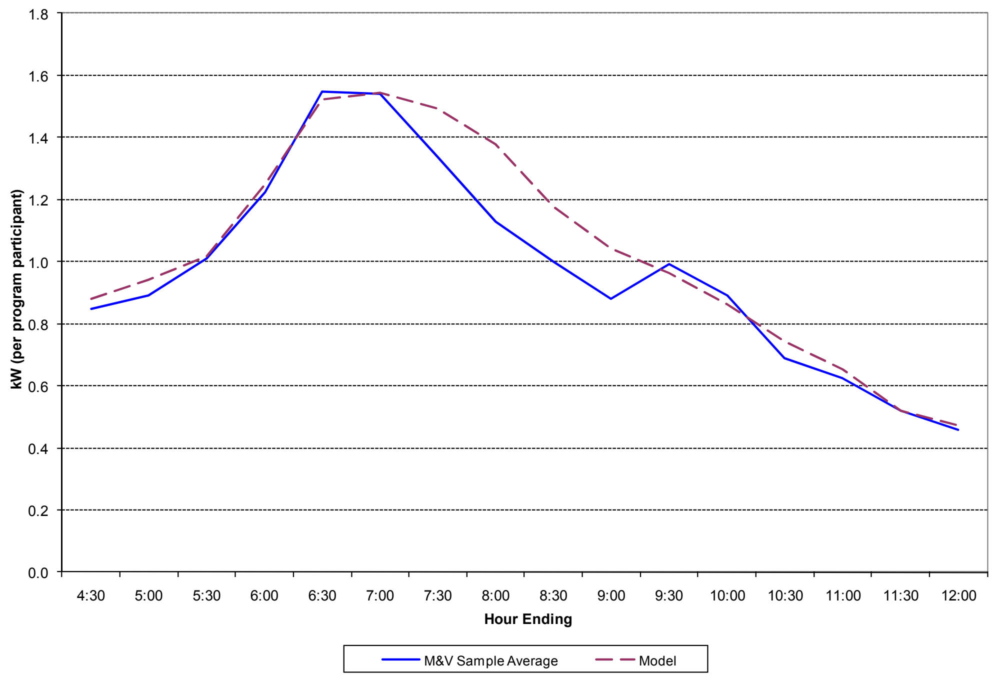
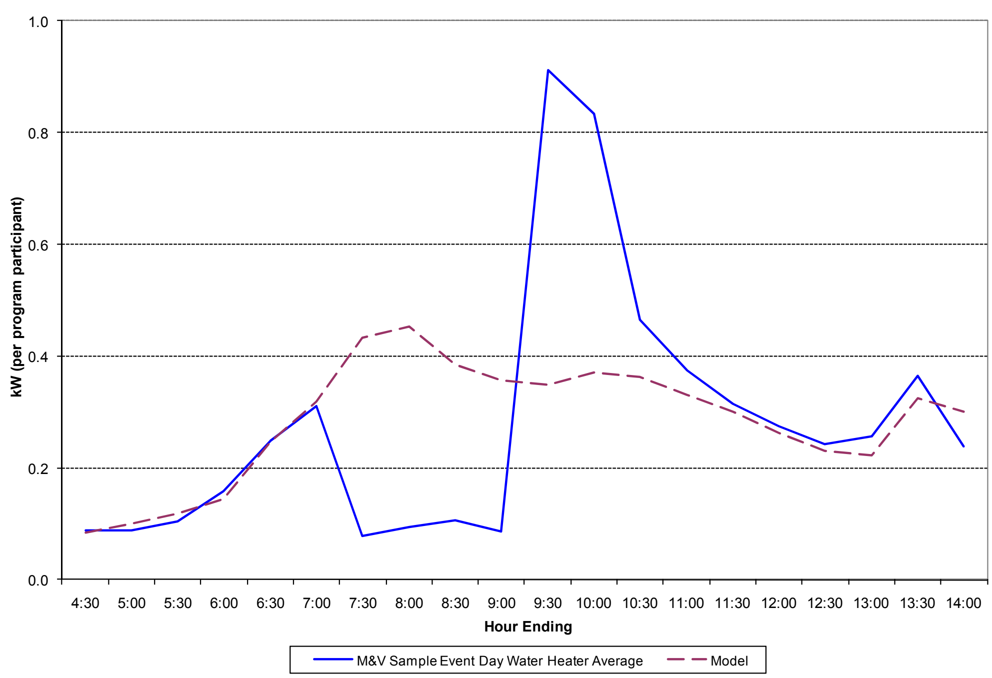


Figure 1-2
Water Heater Baseline Average (from Model) Vs Event Day Average (from M&V Sample)



1.2 Load Impact Projections

Auxiliary strip heating load impact projections were developed for a number of scenarios, defined by the following parameters:

- **Weather Year** - typical or extreme.
- **Percent Cycling** - 50 or 100 percent for auxiliary strip heaters, 100 percent for water heaters
- **Load Impact Adjustment** - a factor applied to the load impact projection to account for rate of non-response

The following tables compare the deemed program savings for load control of central heat pump auxiliary strip heating and the load impact projections for a 100 percent cycling scenario and 50 percent cycling scenario. Table 1-1 shows that when the heat strips are controlled 100 percent of the time (i.e., turned off during the entire control event) load impacts at the time of peak are estimated at 2.6 kW in an extreme (very cold 4°F) year and 2.2 kW in a typical (9°F) weather year. These estimates are above the program's deemed savings of a 1.0 kW per participant.

Table 1-1: Auxiliary Strip Heating -- Load Impact Projections – 100% Control

EnergyWise Auxiliary Strip Heating	PEC Deemed Savings	Load Impact Projections	
		Extreme Weather	Typical Weather
Peak kW Savings	1.0	2.6	2.2
Total kWh Energy Savings	0.9	5.2	4.4

The load impact projections scenario presented in Table 1-2 reflects the savings associated with controlling the heat strips 50 percent of the time (or 15 minutes out of every half-hour). At this level of load control the peak kW savings are significantly lower than both the 100 percent cycling scenario and PEC's deemed savings estimate.

Table 1-2: Auxiliary Strip Heating -- Load Impact Projections – 50% Control

EnergyWise Auxiliary Strip Heating	PEC Deemed Savings	Load Impact Projections	
		Extreme Weather	Typical Weather
Peak kW Savings	1.0	0.43	0.31
Total kWh Energy Savings	0.9	0.86	0.63

Water heating was found to not be sensitive to outdoor temperature – within the same season, the only driver of water heating load was the occupant's hot water usage schedule. Because of this, there was no load impact scenarios developed for this end use.

The following table includes the deemed program savings for water heating, and the load impact projections for a scenario with 100 percent cycling. Peak load impacts are estimated at 0.38 kW, well below the program's deemed savings of 0.8 kW per participant. The snapback is estimated at -0.57 kW per participant. The projected total kWh energy savings for an average water heating load control event is 0.13 kWh per participant. This includes the reduction in load during the two-hour control period and the increase in load (snapback) that occurs during the hour immediately following the control event.

Table 1-3: Water Heater -- Load Impact Projections – 100% Control

EnergyWise Water Heating	PEC Deemed Savings	Load Impact Projections		
		7 to 8 AM	8 to 9 AM	9 to 10 AM
Peak kW Savings	0.8	0.38	0.32	-0.57
Total kWh Energy Savings	0.9	0.70		-0.57

1.3 Non-Response Rates

A non-responsive unit is defined as a participating appliance that was operating at the time of the event, that did not reduce its load as a result of the event, and that does not have a record of an event opt-out. The two most common reasons for non-responsive units are signal problems (permanent or temporary) and DLC device malfunction.

Non-response rates are estimated to be about 10 percent for auxiliary strip heaters and about 15 percent for water heaters. In general, residential demand response programs where the direct load control device is inside the home (such as this winter program) have higher non-response rates than programs where the device is outside. The mountain terrain of this region may also account for some of the low non-response rate. KEMA did not attempt to investigate device malfunctions, but this is unlikely early in the program, when all devices are new.

1.4 Recommendations

The measurement and verification study conducted in the winter of 2009/2010 was the first of two M&V efforts planned by PEC and provides valuable information that can be used to improve the future load impacts of PEC's EnergyWise winter program. This initial M&V effort identified several performance improving opportunities that will be further investigated in future program activities and M&V efforts. Because this M&V study was conducted shortly after program launch, the results are derived from a relatively small sample of early program adopters. The follow-up M&V that is planned for the winter of 2011/2012 should provide additional data with which to make a comprehensive assessment of future load impacts.

1. Increase the percent control for the central heat pump auxiliary strip heater program to 100 percent. Fifty percent cycling proved to be a very mild level of cycling that provided minimal savings.

2. Investigate options to reduce the level of snapback observed in water heating. These may include a staggered release from direct load control, which would cause snapback to spread over several hours. However, it would also cause some program participants to be in control mode longer than others. The consequences of such release have to be explored carefully, and possibly paired with customer research.

3. Monitor the rate of non-response observed in the winter program. Due to the nature of these appliances and mountain terrain in this region, it is unclear, based on the activity conducted to-date, if the winter program can achieve the low rates of non-response observed in the summer program.

4. Conduct further M&V activities, with the following purposes:

    a. Understanding the load patterns and potential load impacts of program participants that are not first adopters. There is substantial market research in the energy industry that proves that first adopters of a program such as EnergyWise tend to be different than those that join as the program matures. First adopters tend to be more focused on the environmental message of a program like this, and potentially more likely to tolerate discomfort.

    b. Investigating whether 100 percent cycling increases auxiliary strip heating snapback or not.

    c. Investigating whether any actions taken to reduce non-response rates and water heating snapback are successful.

2. Winter 2009/2010 EnergyWise Load Impact Estimates

At the beginning of the 2009/2010 winter season there were 204 water heaters and 130 strip heaters enrolled in the EnergyWise program and because of the small number of program participants at that time, PEC and KEMA recruited all program participants. The final sample size upon which the following results were based included 79 water heaters and 73 strip heaters.

Additional details regarding sample design, weather data, load data and model specifications can be found in the appendices to this report.

There were seven winter M&V events conducted in the 2009/2010 season. This section summarizes the load impact estimates obtained during each of these events, for both central heat pump auxiliary strip heating and water heating.

2.1 Heat Pump Auxiliary Strip Heat Load Impacts

2.1.1 Average Auxiliary Strip Heat Load and Load Impacts

The direct load control of heat pump auxiliary strip heating for the M&V events conducted during the 2009/2010 season consisted of 50 percent run time cycling (i.e., strip heat was allowed to run fifteen minutes out of every half hour).

Figure 2-1 and Figure 2-2 illustrate the comparison between the load model estimates developed for this end-use and the average load of the logged appliances.

The first figure is for weekdays with no events. It is clear that the model provides a good representation of the load. This is important because the model is used to estimate the baseline – what strip heater use would have been if there had been no event – and, therefore, constitutes the basis for estimating the program's load impacts.

The second figure is for weekdays with events. Event days are represented by the solid blue line, and the estimated baseline is represented by the broken line. The effect of the event is visible, and the event day load and estimated baseline match well in the hours surrounding the event.

Figure 2-1: Auxiliary Strip Heat Baseline Average (from Model) Vs Non-Event Day Average (from M&V Sample)

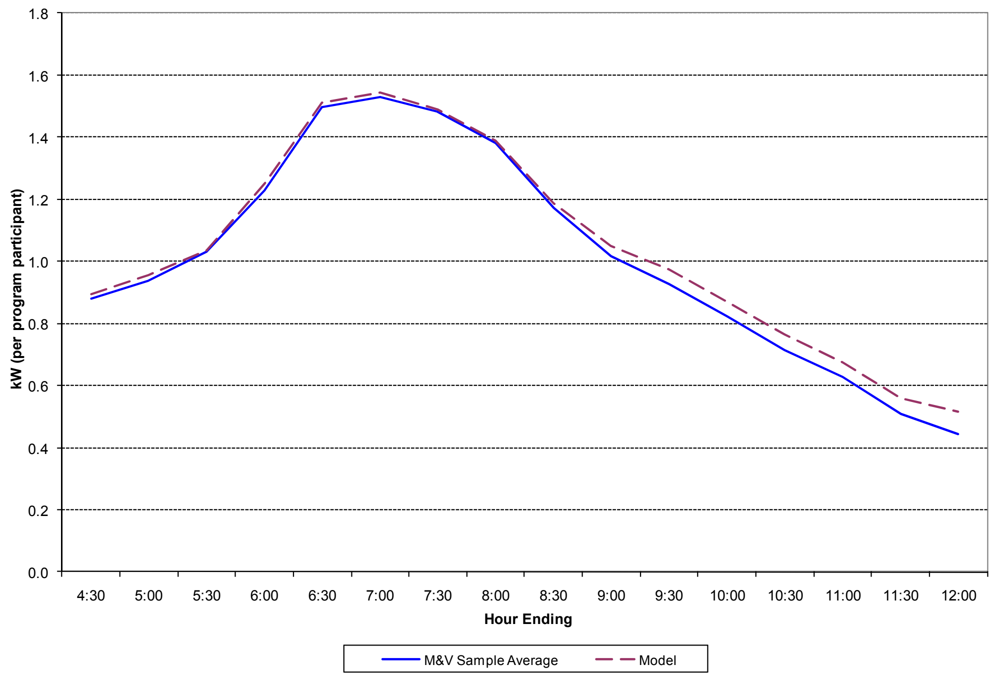
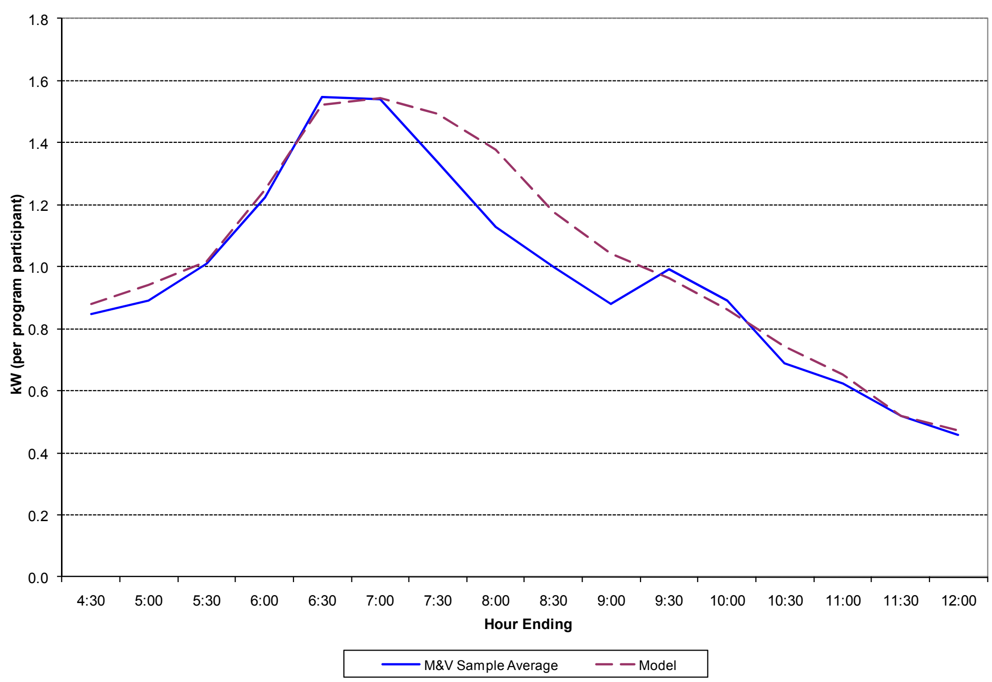


Figure 2-2: Strip Heater Baseline Average (from Model) Vs Event Day Average (from M&V Sample)



2.1.2 Event Day Auxiliary Strip Heat Load Impacts

This section presents the estimated load impacts for central heat pump auxiliary strip heating during each of the M&V events conducted in the 2009/2010 winter season. Table 2-1 lists the day of each event, the minimum and maximum temperatures observed that day, the estimated kW and kWh from the events' load reduction, the corresponding snapback, and whether the half-hourly event load impacts estimated are statistically different from zero.

Of the seven events conducted, only four had half-hourly load impact estimates that were statistically different from zero. In three of these four events with non-zero load impacts, two of the four event half-hour intervals were statistically different from zero. In one of the four events, only one of the four intervals was statistically different from zero. This is due to two factors: the low average natural duty cycle of auxiliary strip heating combined with a moderate level of direct load control applied in the winter of 2009/2010, and a relatively high level of non-response. Both of these factors are discussed in following sections.

Table 2-1: EnergyWise Auxiliary Strip Heat Load Impact Estimates

Date	Min/Max Daily Temperature (°F)*	kW		kWh		
		Event Load Reduction	Event Snapback	Event Load Reductio n	Event Snapback	Impact not Zero**
16-Dec-09	30/45	0.0	0.1	0.0	0.1	
7-Jan-10	20/41	0.3	-0.1	0.4	0.0	
15-Jan-10	23/61	0.2	-0.2	0.3	-0.2	7:30
20-Jan-10	39/69	0.2	-0.1	0.3	0.0	
27-Jan-10	26/42	0.4	0.1	0.5	0.3	7:30, 8:00
16-Feb-10	17/29	0.4	-0.2	0.5	-0.1	8:00, 8:30
25-Feb-10	25/42	0.3	-0.1	0.6	-0.1	8:30, 9:00

* Source: National Oceanic and Atmospheric Administration (NOAA). Weather station: Asheville, NC.

** Estimated load impacts in the half-hours listed are statistically different than zero at the 90% confidence level.

Auxiliary strip heating load during the seven EnergyWise M&V events is illustrated in the following figures. The event days that had a statistically significant impact are January 15 (Figure 2-5), January 27 (Figure 2-7), February 16 (Figure 2-18) and February 25 (Figure 2-19). The effect of lower temperatures is clearly visible: on February 16, when the minimum temperature of the day was 17°F, average load in the half hour preceding the event was 2.3 kW. On December 16 (illustrated in Figure 2-3), when the minimum temperature of the day was 30°F, the average load in the half hour preceding the event was 0.7 kW.

Figure 2-3: EnergyWise Auxiliary Strip Heat Event: December 16, 2009

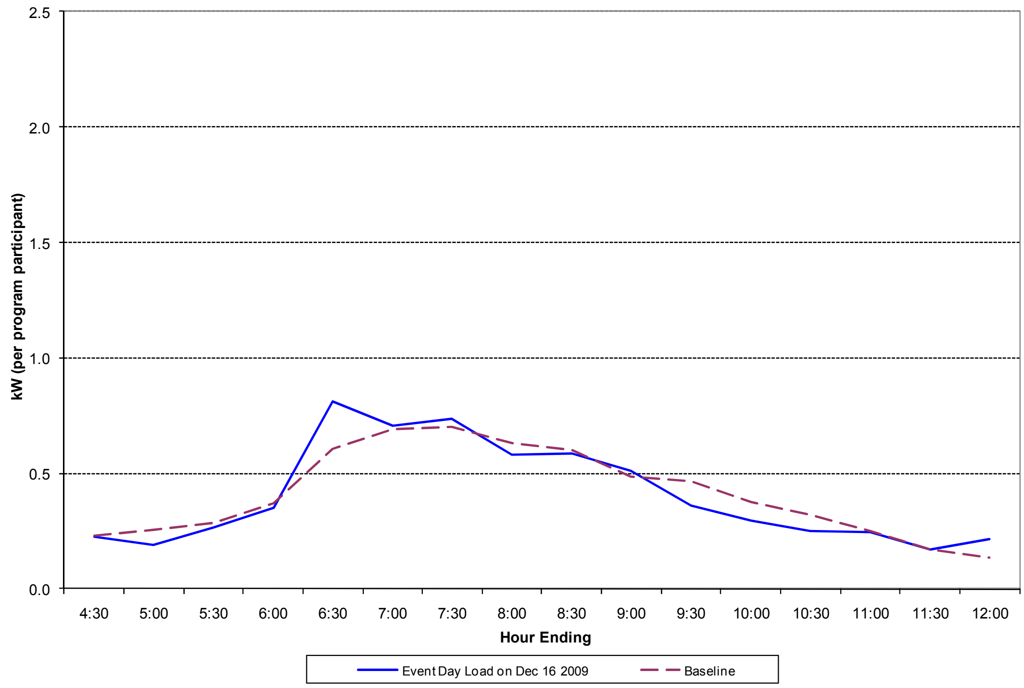


Figure 2-4: EnergyWise Auxiliary Strip Heat Event: January 7, 2010

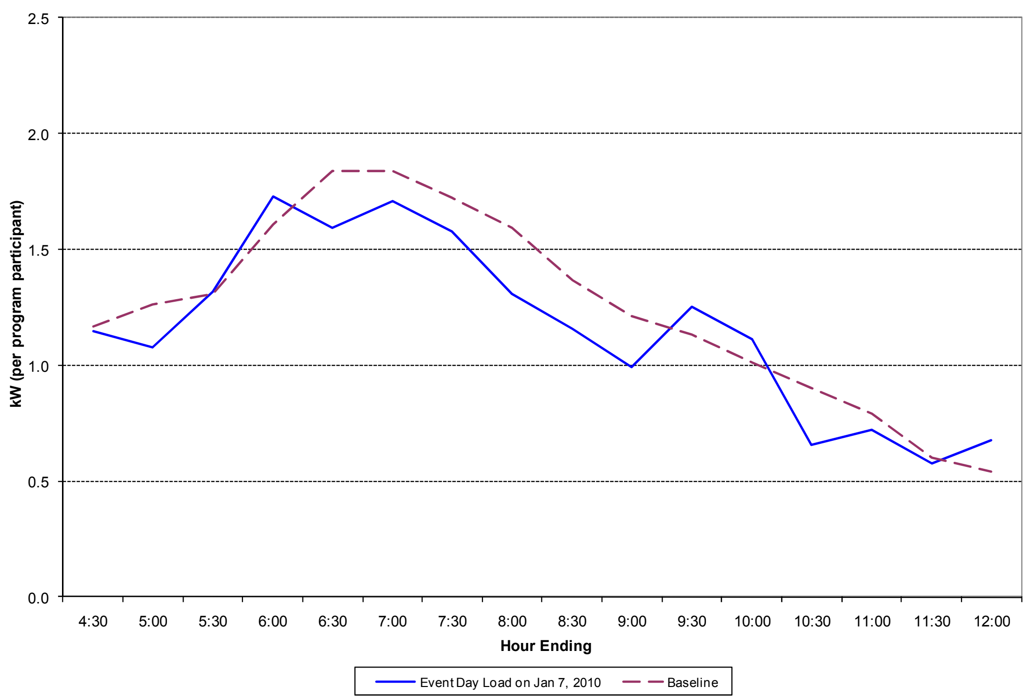


Figure 2-5: EnergyWise Auxiliary Strip Heat Event: January 15, 2010

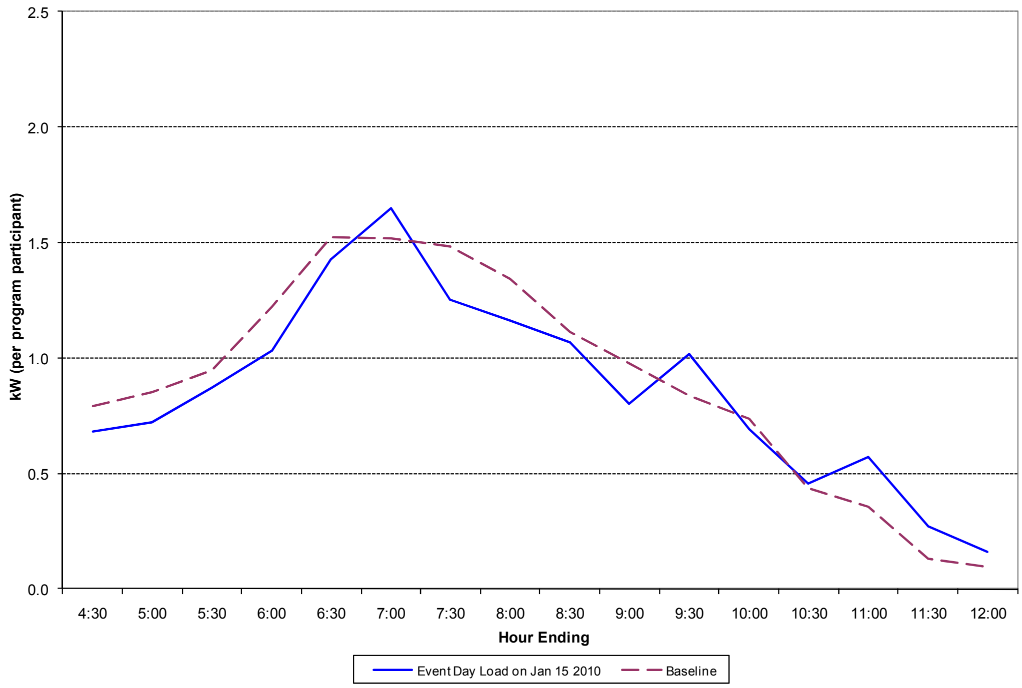


Figure 2-6: EnergyWise Auxiliary Strip Heat Event: January 20, 2010

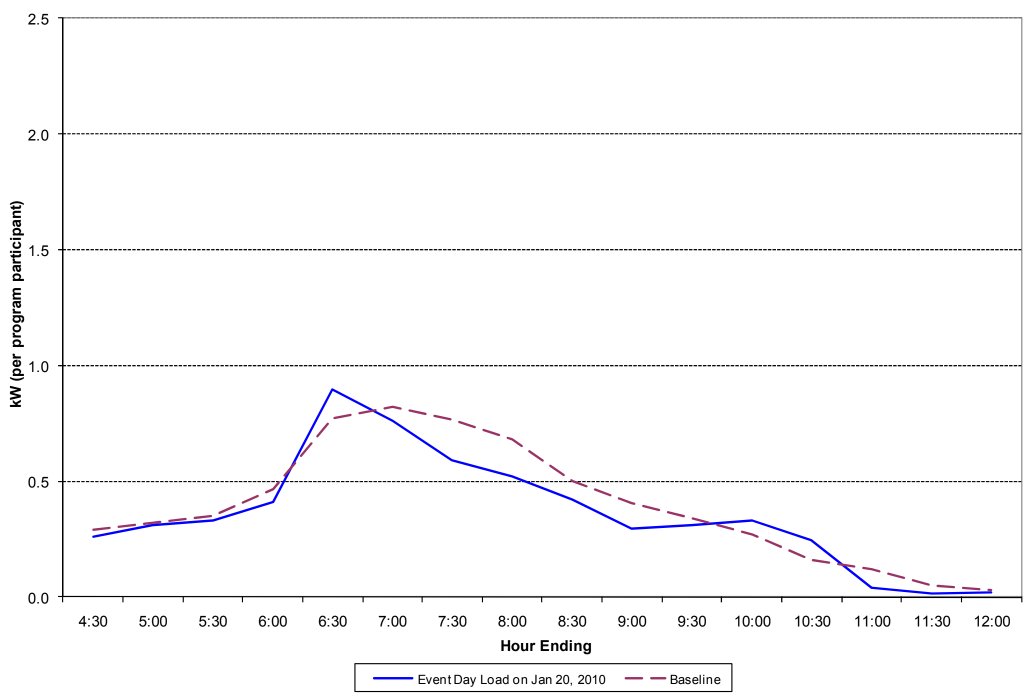


Figure 2-7: EnergyWise Auxiliary Strip Heat Event: January 27, 2010

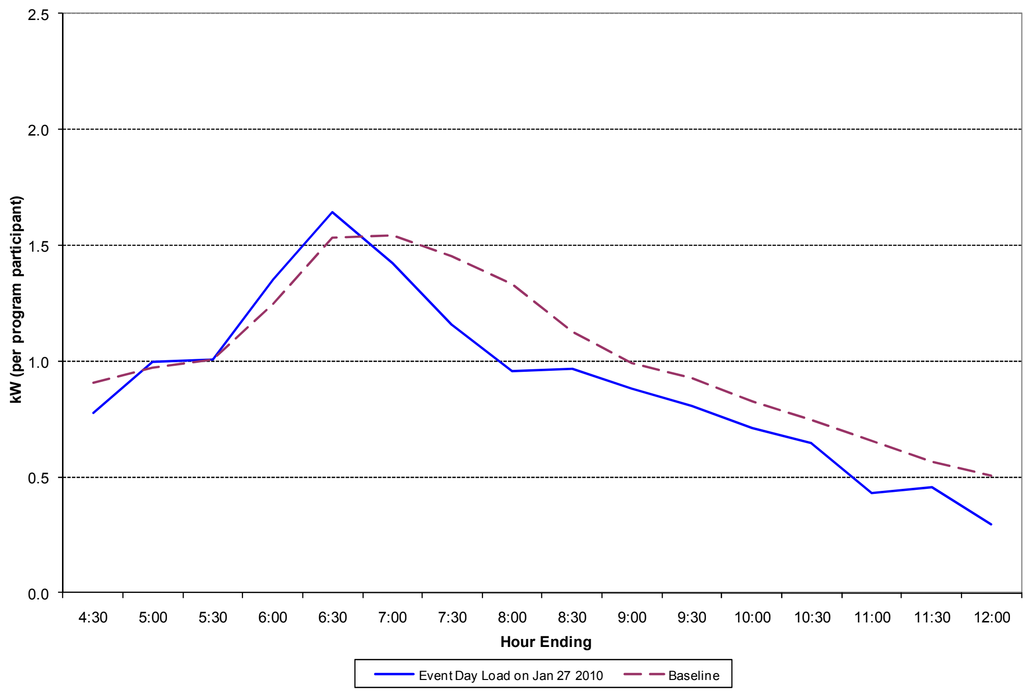


Figure 2-8: EnergyWise Auxiliary Strip Heat Event: February 16, 2010

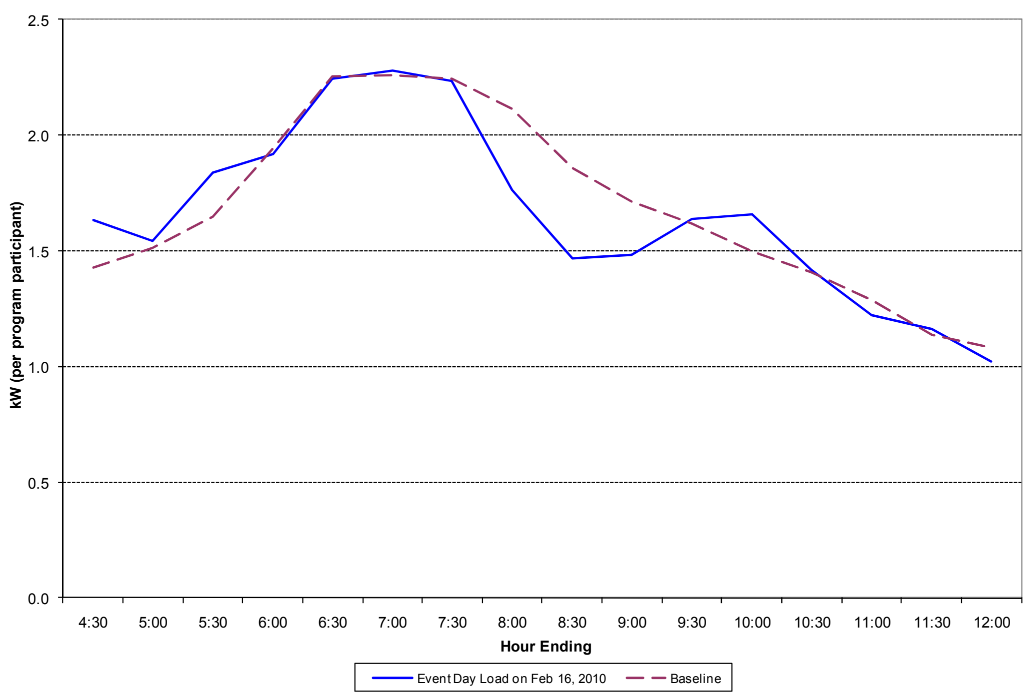
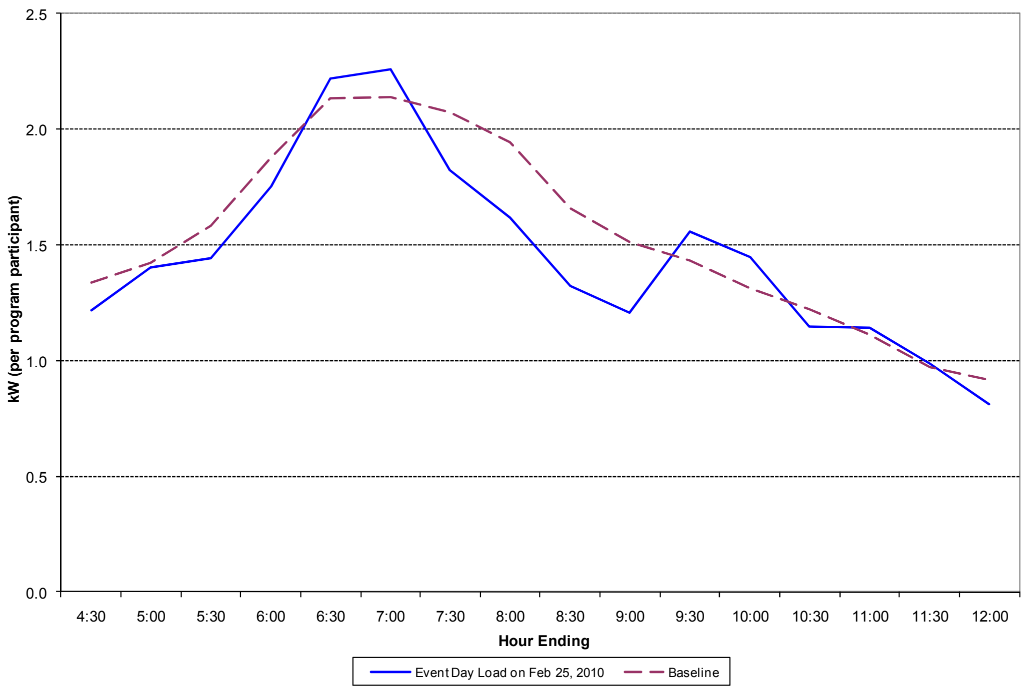


Figure 2-9: EnergyWise Auxiliary Strip Heat Event: February 25, 2010



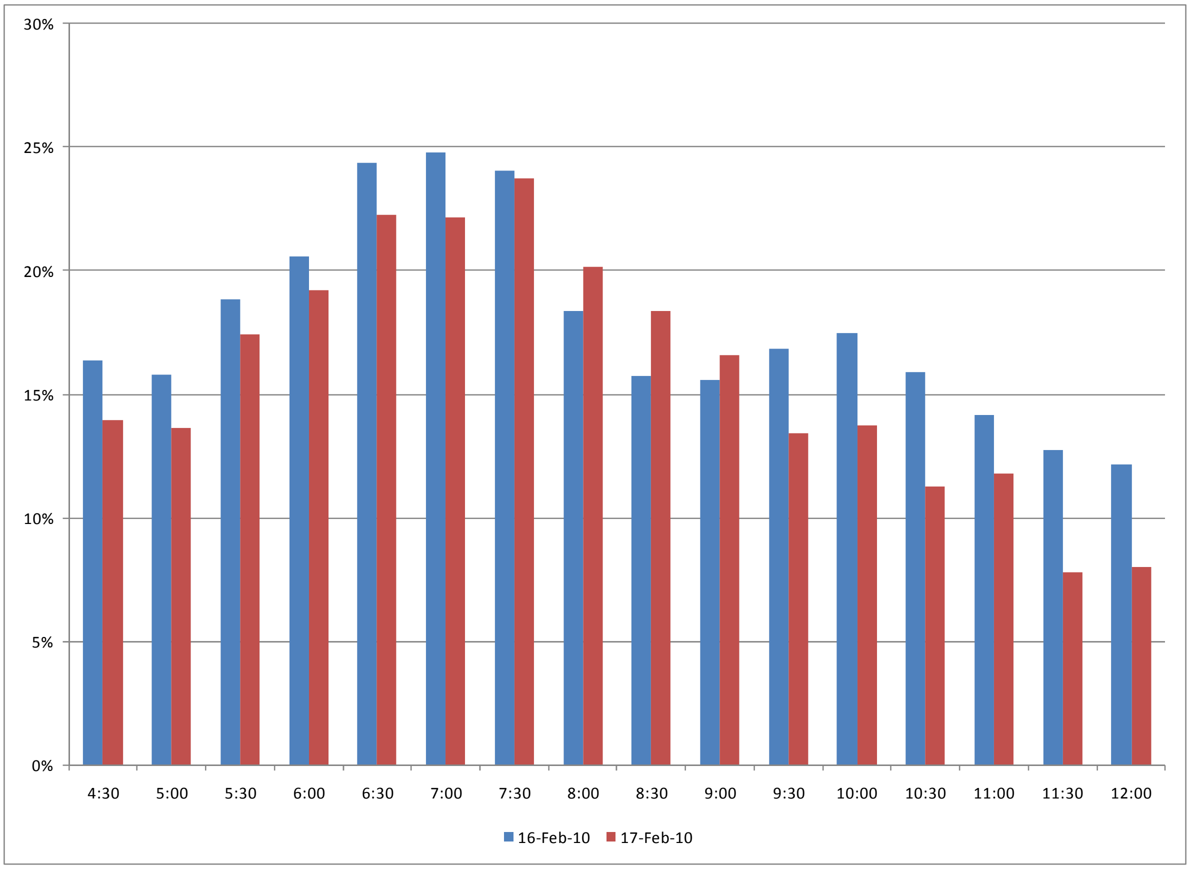
2.1.3 Auxiliary Strip Heat Duty Cycle

During the winter 2009/2010 M&V events, central heat pump auxiliary strip heating was cycled at 50 percent of run time, which means they were allowed to operate for 15 minutes out of every half hour. When controlling based on percent run time, instead of using the adaptive algorithms that are available in the summer program, only units with duty cycles greater than the control percent run time contribute to the event's load impact. For example, a unit that has a duty cycle of 20 percent (it runs 12 out of every 60 minutes) will not have a significant load impact – it will quickly adapt to the load control and simply run at the time that the unit is allowed to run, but it will run for the same number of minutes that it would have otherwise. A unit that has a duty cycle of 55 percent (it runs 33 out of every 60 minutes) will have a load reduction of 5 percent, or the load corresponding to 3 minutes out of every hour.

Figure 2-10 illustrates the average duty cycle of participating auxiliary strip heating on February 16 (a Tuesday event day, with minimum and maximum daily temperatures of 17 and 29 °F) and February 17 (a non-event day, with minimum and maximum daily temperatures of 21 and 31°F). The highest average duty cycles for each of these days were between 20-25% and occur during the half-hours ending 6:30 am, 7:00 am and 7:30 am, which are immediately before or during the beginning of a typical winter load control event.

This study found that the average duty cycle of auxiliary strip heating is below the 50 percent level of direct load control that was used during the winter events of 2009/2010. This resulted in zero to low impacts, and correspondingly, zero to low snapback.

Figure 2-10: Average Auxiliary Strip Heating Duty Cycle during the Event Day of February 16, 2010 and the Non-Event Day of February 17, 2010



2.2 Water Heater 2009 Load Impacts

2.2.1 Average Water Heater Load and Load Impacts

Figure 2-11 provides a comparison between the load model estimates developed for this end-use and the average load of the logged appliances.

The first figure is for weekdays with no events. It is clear that the model provides a very good representation of the load. This is important because the model is used to estimate the baseline

– what water heater use would have been if there had been no event – and, therefore, constitutes the basis for estimating the program's load impacts.

Figure 2-11: Water Heater Baseline Average (from Model) vs Non-Event Day Average (from M&V Sample)

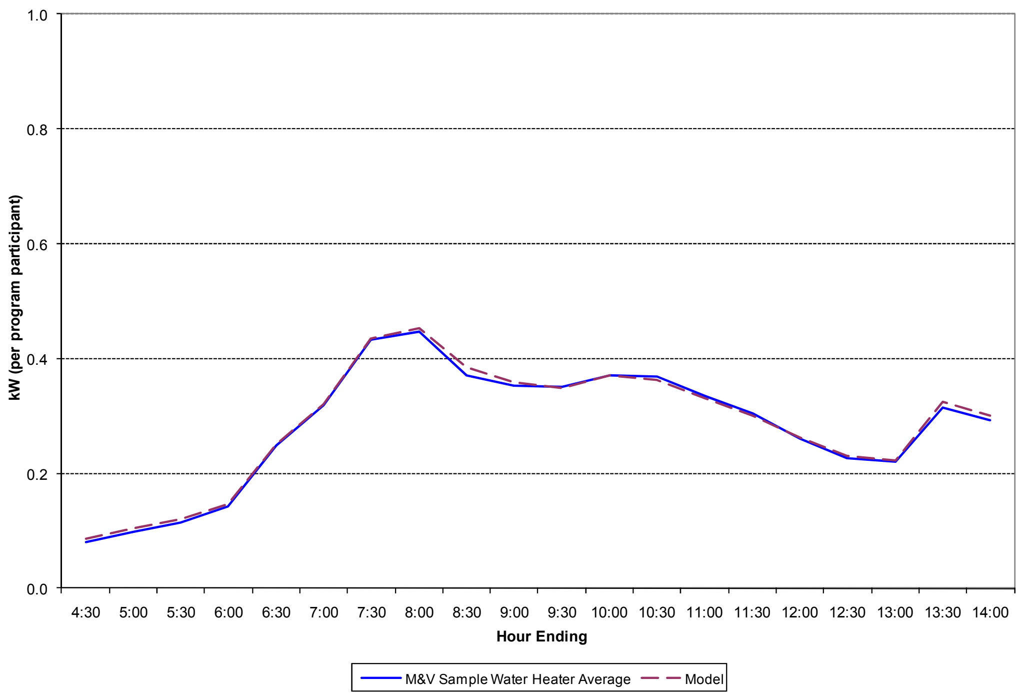
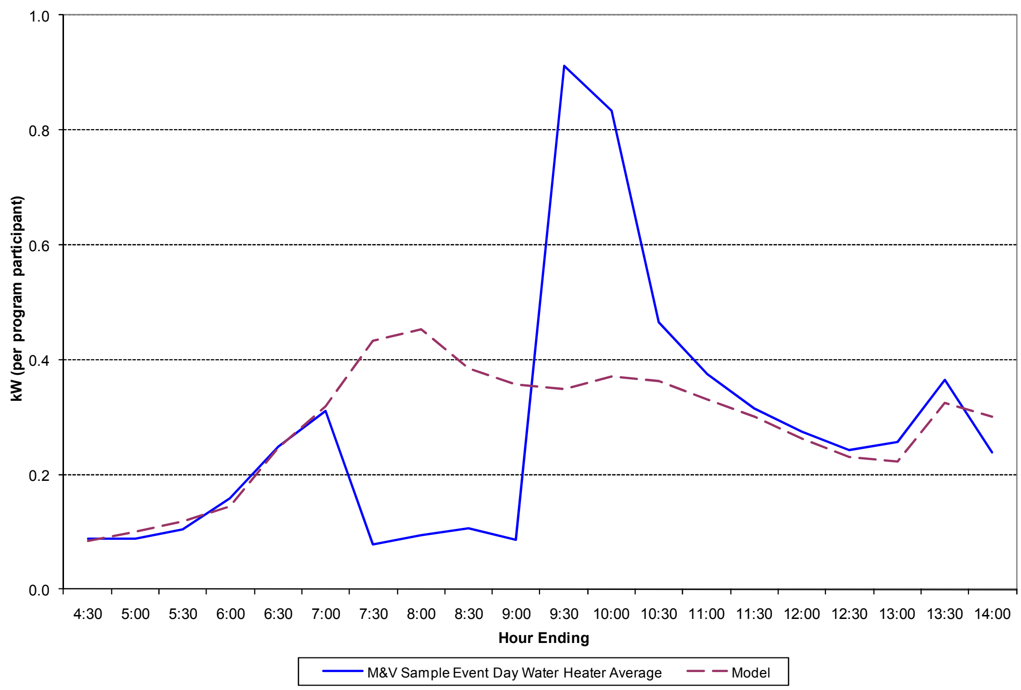


Figure 2-12 represents the average event day load and the corresponding estimated baseline. The baseline provides a good fit for the hours prior to the event and after snapback. However, this figure by itself does not provide enough information to gauge the model's performance at the time of an event. Figure 2-11 indicates that the model does an excellent job at capturing water heating load during the most likely time frame of a potential event – a necessary feature of a good baseline estimate.

Figure 2-12 illustrates the significant effect of the 7:00-9:00 am load control event as well as a very high level of snapback – on average, events had a maximum impact of 0.4 kW per participant, while snapback had a maximum impact of 0.6 kW. The average energy reduction during the event was 0.6 kWh, which is the same as the average energy use during the snapback period. This indicates that a large deployment of water heater controls will require a careful post-event cycling strategy in order to reduce the load impact of the snapback. This is discussed in this report's recommendations.

Figure 2-12: Water Heater Baseline Average (from Model) Vs Event Day Average (from M&V Sample)



2.2.2 Event Day Water Heater Load Impacts

This section presents the estimated water heater load impacts for each of the M&V events conducted in the 2009/2010 winter season. Water heaters were cycled at 100 percent during each of these historical events. This means that water heaters were expected to be completely turned off during the control events. In the absence of event opt-outs (when customers choose to not participate in an EnergyWise event), water heater energy use observed during events is caused by lack of response to the EnergyWise event. Event non-response is discussed in Section 2.2 of this report.

Table 2-2 lists the day of each event, the minimum and maximum temperatures observed that day, the estimated kW and kWh from the events' load reduction, and the corresponding snapback.

Table 2-2: EnergyWise Water Heater Load Impact Estimates

Date	Min/Max Daily Temperature (°F)*	kW (1/2 hour interval)		kWh (cumulative for 2 hours)	
		Maximum Event Load Reduction	Event Snapback	Event Load Reduction	Event Snapback
16-Dec-09	30/45	0.30	-0.41	0.49	-0.41
7-Jan-10	20/41	0.41	-0.59	0.74	-0.58 **
15-Jan-10	23/61	0.39	-0.45	0.65	-0.47
20-Jan-10	39/69	0.39	-0.43	0.66	-0.58
27-Jan-10	26/42	0.43	-0.74	0.77	-0.48 **
16-Feb-10	17/29	0.40	-0.75	0.61	-0.92
25-Feb-10	25/42	0.33	-0.62	0.50	-0.67

* Source: National Oceanic and Atmospheric Administration (NOAA). Weather station: Asheville, NC.

** In this table, the load impact kW is measured in half-hour intervals. In cases where one of the half-hours has a value that is much higher than the other intervals, the resulting cumulative kWh can be lower than what would result from integrating the load impact value provided over the intervals of the event.

Figure 2-13 thru Figure 2-19 present the water heating model baseline usage compared to water heating usage on the actual event day for each of the seven winter M&V control events during the winter of 2009/1010. The estimated maximum load reduction for all of these days falls within a fairly narrow range of 0.3 kW to 0.4 kW. While all days exhibit a sharp snapback immediately following the load control event, the amount of snapback varies from 0.4 kW on January 16 and January 20, to 0.6 kW on February 25 and 0.8 kW on February 18.

The demand (kW) increase immediately following the end of the event is estimated to be higher than the maximum load reduction achieved during each event. The corresponding energy (kWh) increase is estimated to be lower than the energy reduction achieved during each event for five of the seven events. The energy snapback of the last two events is estimated to have been higher than the corresponding energy reduction.

Figure 2-13: EnergyWise Water Heater Event: December 16, 2009

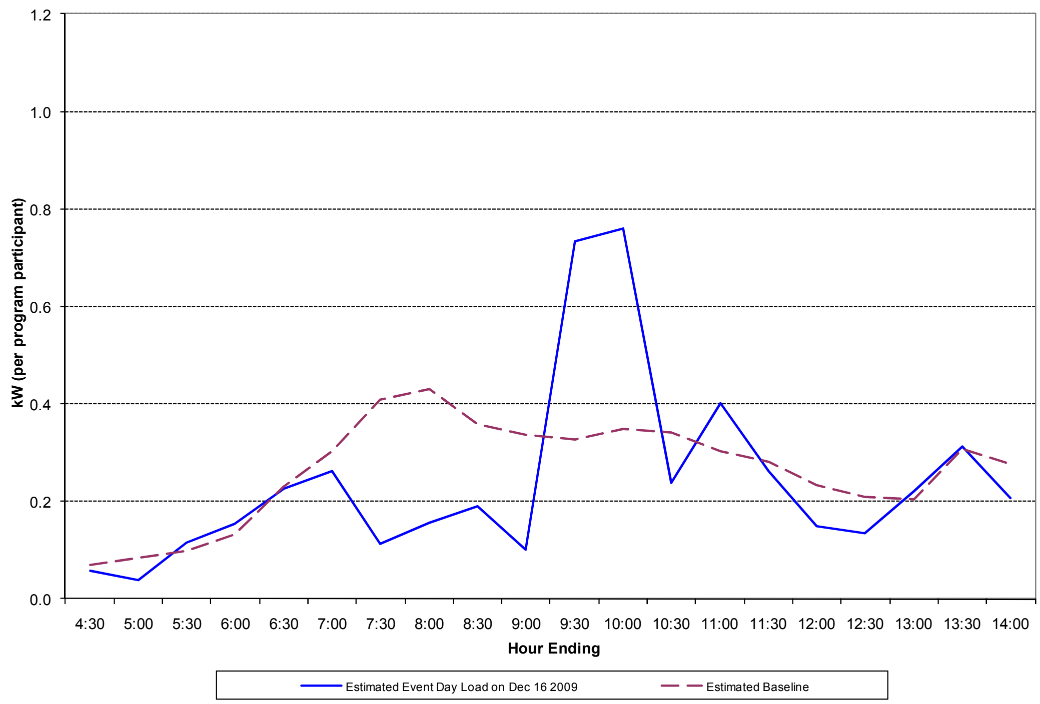


Figure 2-14: EnergyWise Water Heater Event: January 7, 2010

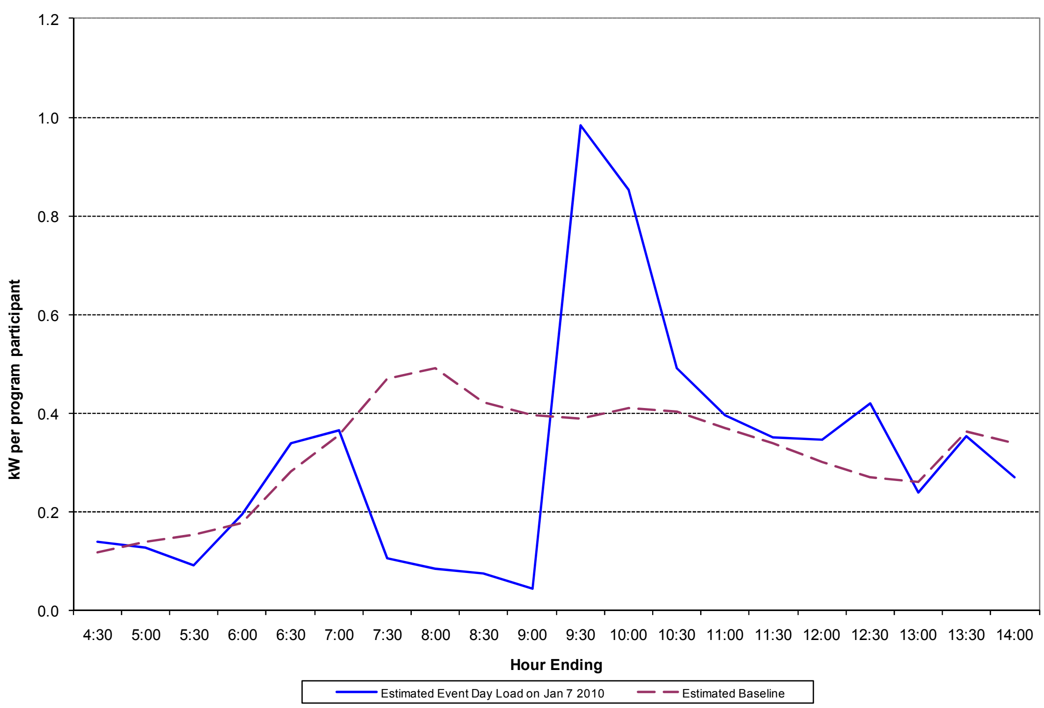


Figure 2-15: EnergyWise Water Heater Event: January 15, 2010

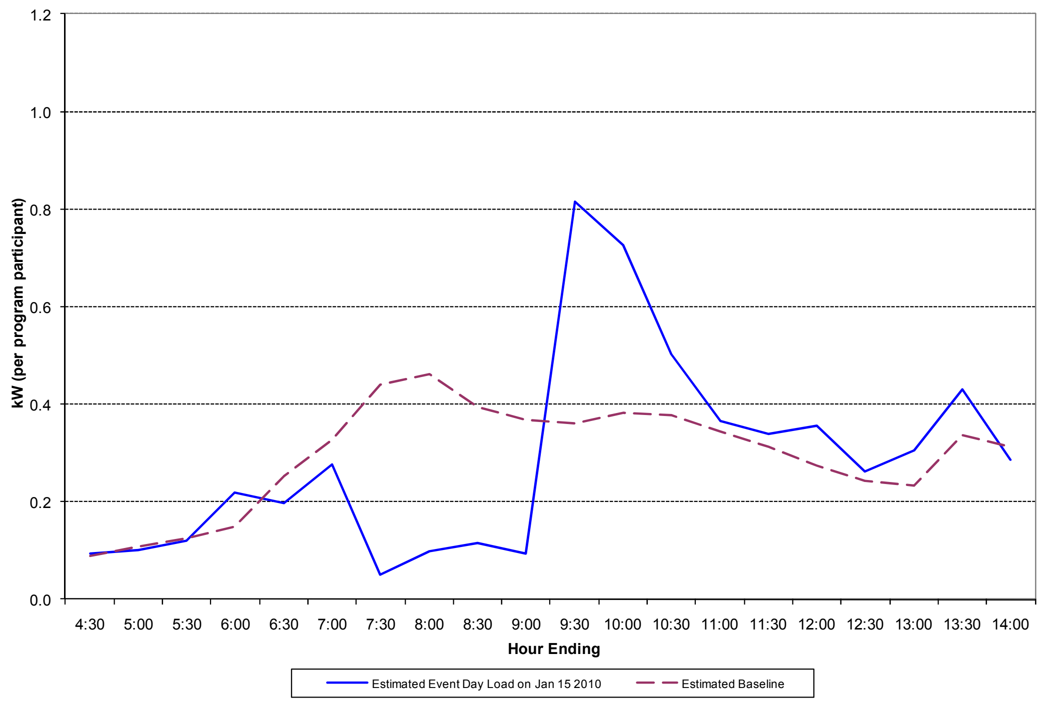


Figure 2-16: EnergyWise Water Heater Event: January 20, 2010

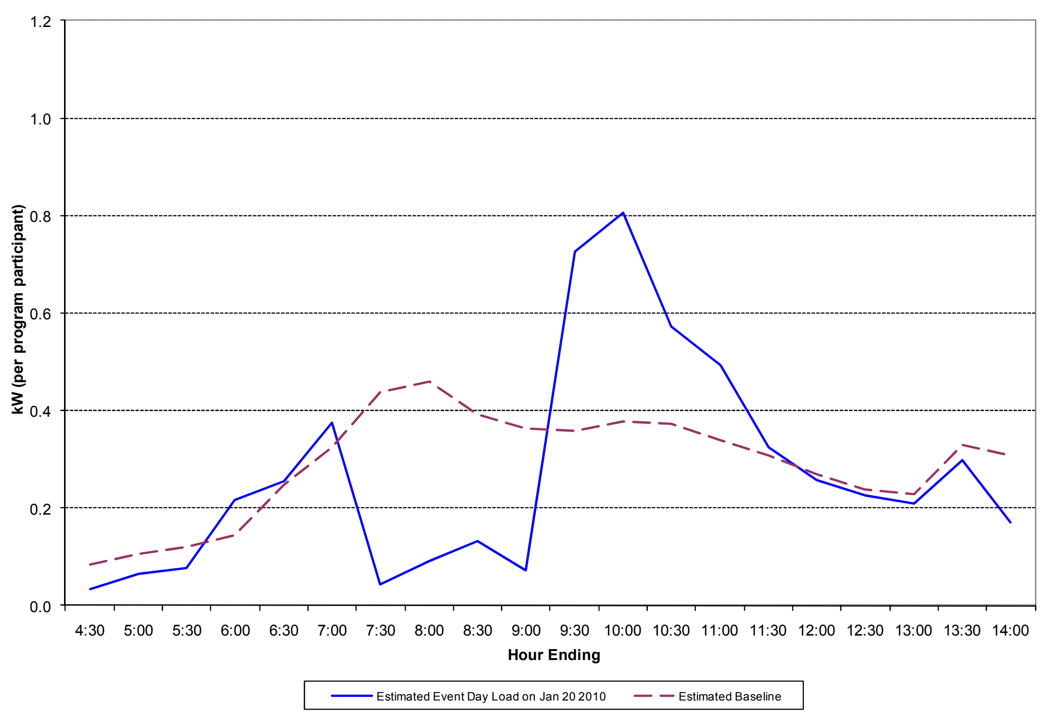


Figure 2-17: EnergyWise Water Heater Event: January 27, 2010

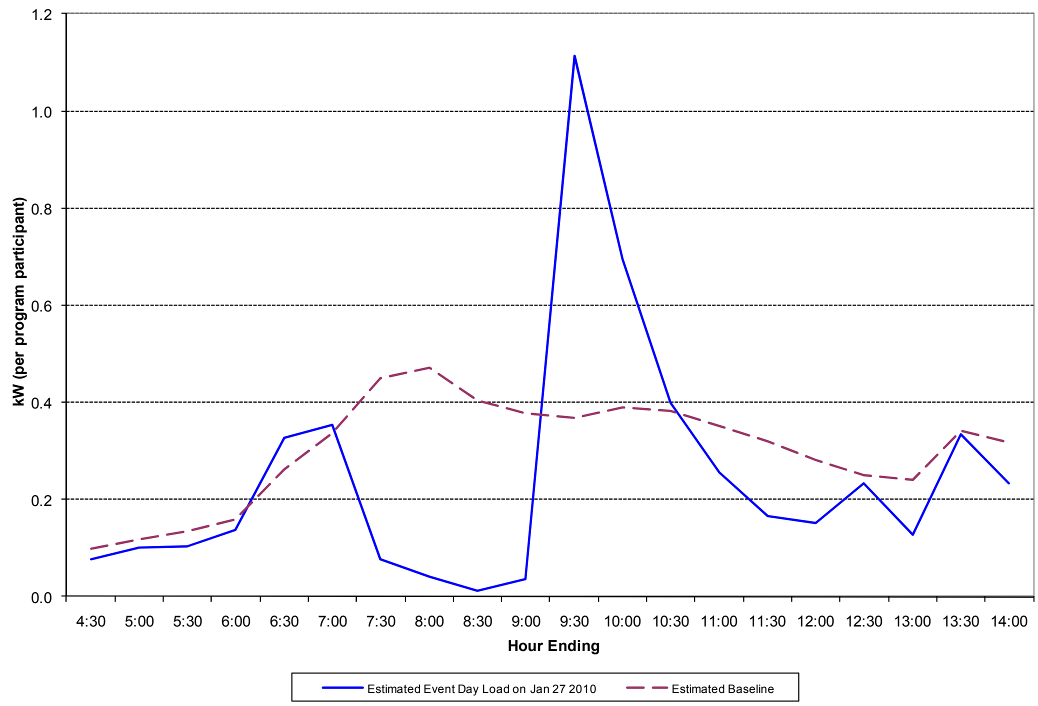


Figure 2-18: EnergyWise Water Heater Event: February 16, 2010

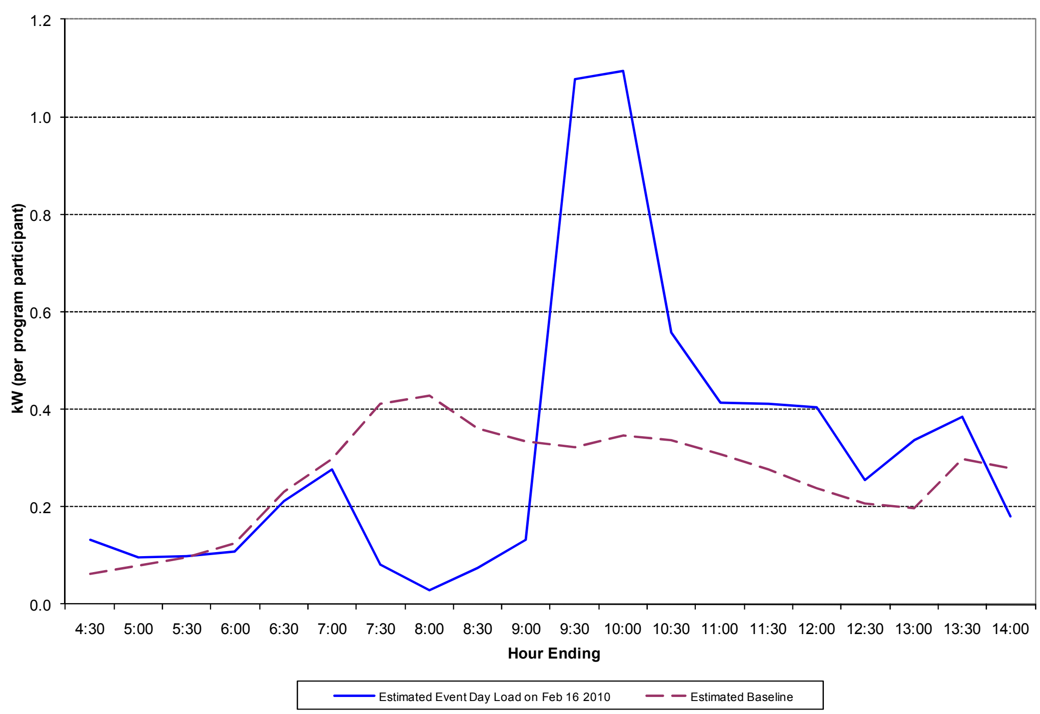
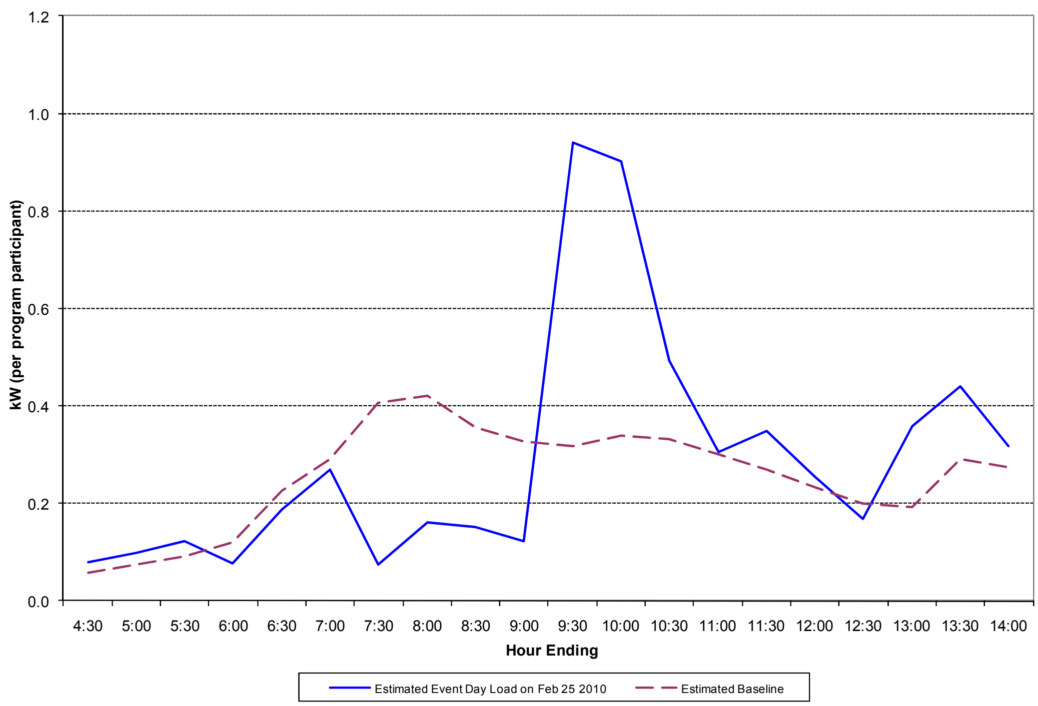


Figure 2-19: EnergyWise Water Heater Event: February 25, 2010



3. Non-Response Rates

A non-responsive unit is defined as a participating appliance that was operating at the time of the event, that did not reduce its load as a result of the event, and that does not have a record of an event opt-out. The two most common reasons for non-responsive units are signal problems (permanent or temporary) and DLC device malfunction.

To quantify non-responsive units, KEMA visually examined the load data for each appliance in the sample, on event days and on the days before and after each event day. The event day load of each sample appliance was classified into one of the following four categories:

1. No control (unit clearly did not respond to the curtailment)
2. Control (unit clearly reduced load in response to the curtailment)
3. The unit's response status cannot be determined from the visual inspection of the load data
4. The unit was not operating during the event

Examples of load data in the first three categories are presented in Appendix B. The non-response rate is based only on units that were clearly not controlled at the time of the event. Units where the response status could not be determined from the load data are deemed to be responsive.

Non-response rates are estimated separately for auxiliary strip heaters and for water heaters, and presented in Table 3-1. This table shows the following:

- The percent of water heaters that did not experience usage at the time of the M&V events is fairly constant among all events, at about 20 percent. This shows that water heater use is schedule-driven and is not influenced by outdoor temperature[1].

- The percent of auxiliary strip heaters that did not experience usage at the time of the M&V events varied from a low of 21 percent on January 27 (when the minimum temperature of the day was 26 and the maximum was 42 degrees), to a high of 51 percent on January 20 (when the minimum temperature of the day was 39 and the maximum was 69 degrees). Auxiliary strip heating use exhibits a high correlation to cold weather, while water heating exhibits almost none.

[1] While water coming into a water heater may be warmer in the summer than in the winter, water temperature within the same winter season does not vary enough to cause a difference in water heating loads.

- The share of non-responsive strip heaters varies from 3 percent to 11 percent. For water heaters it varies from 6 to 18 percent.

- The share of auxiliary strip heaters that are clearly responsive fluctuates between 3 and 15 percent. For water heaters it varies from 16 to 29 percent. Determining a clear response in strip heaters is more difficult than in water heaters. This is because water heaters were subject to 100 percent control (they were not allowed to operate during the control period), whereas strip heaters were subject to 50 percent control (they were allowed to operate for 15 minutes, and then turned off for 15 minutes). If a strip heater is naturally cycling at less than every 15 minutes, it can still be under control and maintain its natural cycle.

Table 3-1: EnergyWise Non-Response Rates
Winter of 2009/2010

Appliance	EnergyWise Event Dates	Percent of non-responsive units	Percent of responsive units	Percent of units with inconclusive status	Percent of units with no morning usage	Total
Strip Heater	12/16/2009	5%	3%	49%	42%	100%
	1/7/2010	7%	7%	63%	23%	100%
	1/15/2010	4%	5%	63%	27%	100%
	1/20/2010	3%	5%	41%	51%	100%
	1/27/2010	5%	5%	68%	21%	100%
	2/16/2010	11%	15%	51%	23%	100%
	2/25/2010	8%	14%	53%	25%	100%
Water Heater	12/16/2009	18%	16%	46%	20%	100%
	1/7/2010	6%	29%	44%	20%	100%
	1/15/2010	10%	18%	52%	20%	100%
	1/20/2010	13%	18%	49%	20%	100%
	1/27/2010	8%	27%	44%	22%	100%
	2/16/2010	6%	29%	42%	23%	100%
	2/25/2010	15%	25%	41%	19%	100%

In general, residential demand response programs where the direct load control device is inside the home (such as this winter program) have higher non-response rates than programs where the device is outside. The mountain terrain of this region may also account for some of the low non-response rate. KEMA did not attempt to investigate device malfunctions, but this is unlikely early in the program, when all devices are new.

4. Load Impact Projections

4.1 Auxiliary Strip Heat Load Impact Projections

This section details the load impact projections that were estimated for the EnergyWise winter program under different scenarios.

Based on the data collected during the 2009/2010 winter season, auxiliary strip heating control events are estimated to have no snapback. Because this data was collected at a very low level of event cycling (50 percent), KEMA recommends that the absence of snapback be confirmed in subsequent M&V studies. However, the absence of snapback is plausible for two reasons:

1. Events end at 9 AM – at the time that many participants have left their homes and the thermostat is likely to be set back, requiring no additional heating even if the house is at a temperature lower than usual.
2. Even in households where the thermostat is not set back, the reduced or delayed strip heater activity may give enough time for heat pumps to make up for the home's heat loss, reducing or eliminating the need for the supplemental heating.

4.2 Auxiliary Strip Heat Load Impact Projections Scenario Parameters

Load impact projections were developed for all combinations of the parameters listed in Table 4-1. These parameters are described below.

- **Weather Year** describes the two temperature scenarios employed in the load impact projections: *typical* for a year where the temperatures are in the median of the hourly temperatures observed from 2000 to 2009, and *extreme*, for the lowest temperatures observed in the same period.
- **Percent Cycling** is the percent of the hour that appliances are allowed to run. At 50 percent cycling, an appliance is allowed to run 15 minutes of every half hour. At 100 percent cycling, appliances are entirely shut down. Load impact projections were developed for 50 percent cycling (the level of cycling utilized in the 2009/2010 season) and 100 percent cycling (the level of cycling that is likely to be utilized in subsequent seasons.)

- **Load Impact Adjustment** is a factor applied to the load impact projection to account for rate of non-response. It includes a “non-response” option (for units that did not respond to the event), and a “no adjustment” option, representing a 0 percent non-response rate.

Table 4-1
EnergyWise Winter Load Impact Projection Scenario Parameters

Weather Year	Percent Cycling	Load Impact Adjustment
1. Typical 2. Extreme	1. 50% 2. 100%	1. Non-Response Adjustment 2. No Adjustment

The following subsection includes examples of some of these scenarios, and discussions of the influence of the different parameters in the corresponding load impacts.

4.3 Examples of Load Impact Projection Scenarios for Auxiliary Strip Heat

4.3.1 Weather Year Effect

The scenarios include two types of weather year: *Typical* and *Extreme*. This section illustrates the influence of the weather year parameter in the load impact projections.

Figure 4-1 and Figure 4-2 show the load impact for strip heater cycling at 100 percent, on the coldest day of the year. The load impacts are adjusted by the non-response factor, which is about 10 percent for strip heaters.

The minimum daily temperature in this scenario is 12°F in a typical year and about 4°F in an extreme year.

The load impacts are 1.6 to 1.9 kW per hour for the typical year, and 2.4 to 2.8 kW per hour for the extreme year, or about 45 percent more in the extreme year than in the typical year.

Figure 4-1: Auxiliary Strip Heat Load Impact Projection

Weather Year: Typical Control Percent: 100%
Load Impact Adjustment: Non-Response

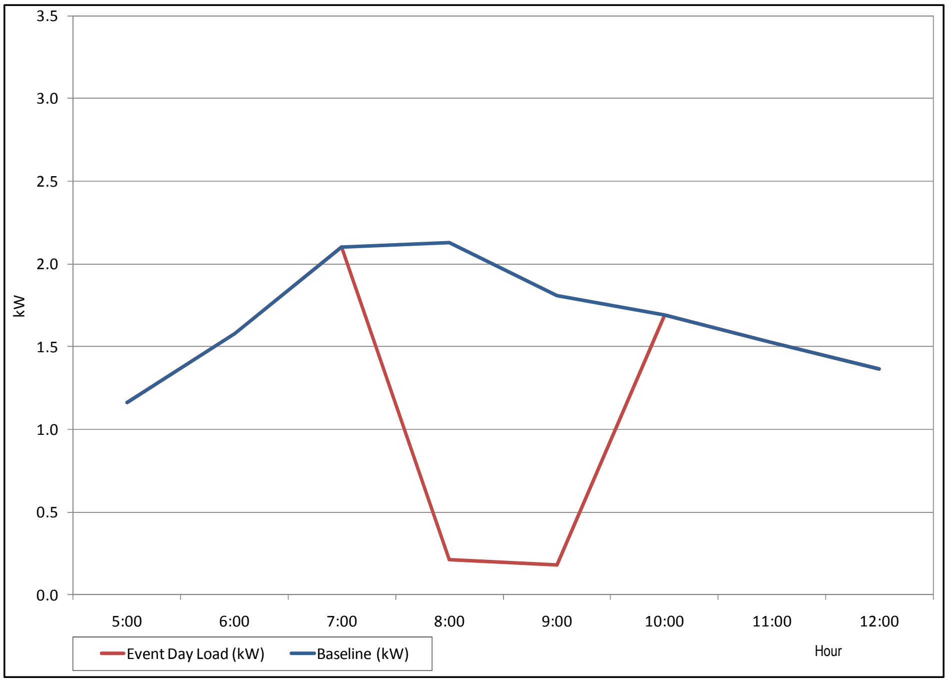
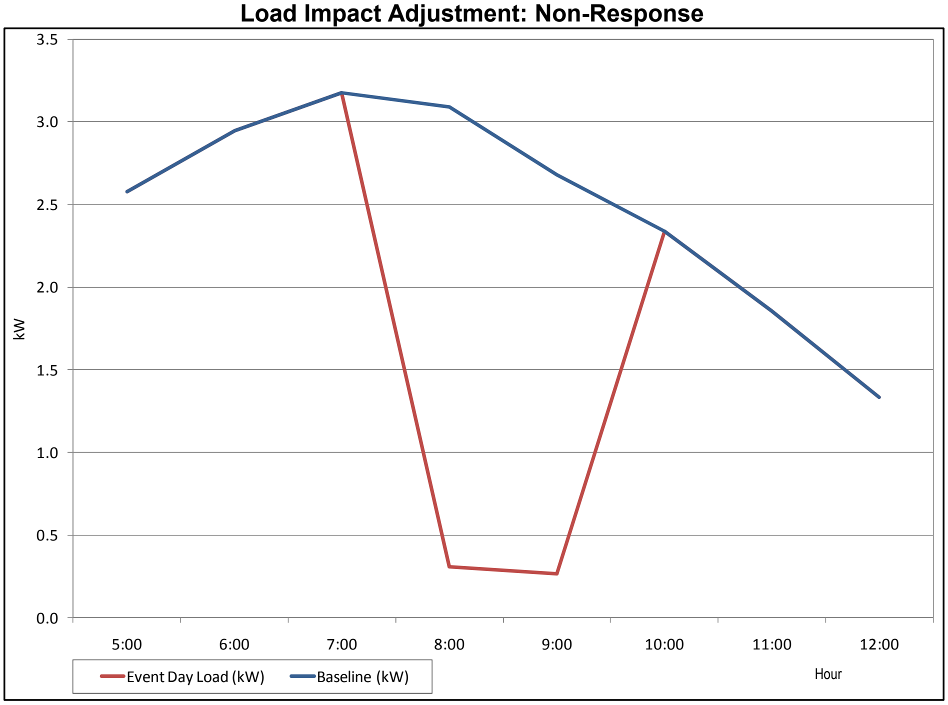


Figure 4-2: Auxiliary Strip Heat Load Impact Projection

Weather Year: Extreme Control Percent: 100%
Load Impact Adjustment: Non-Response



4.3.2 Percent Cycling Effect

Load impacts for auxiliary strip heaters were estimated at 50 percent and 100 percent cycling. This section illustrates the influence of percent cycling in the load impact projections.

The examples in this section are for the coldest day in an extreme weather year. The estimates are adjusted with the non-response rate.

Table 4-2: Auxiliary Strip Heat Load Impact Projections
Weather Year: Extreme Control Percent: (See table)
Load Impact Adjustment: Non-Response

Month	Minimum Daily Temperature	50%Cycling		100% Cycling	
		7 to 8 AM	8 to 9 AM	7 to 8 AM	8 to 9 AM
November	15°F	0.2	0.2	0.9	0.6
December	9°F	0.4	0.3	2.2	1.9
January	4°F	0.7	0.5	2.7	2.4
February	9°F	0.7	0.4	2.6	2.2

Figure 4-3: Auxiliary Strip Heat Load Impact Projection
Weather Year: Extreme Control Percent: 50%

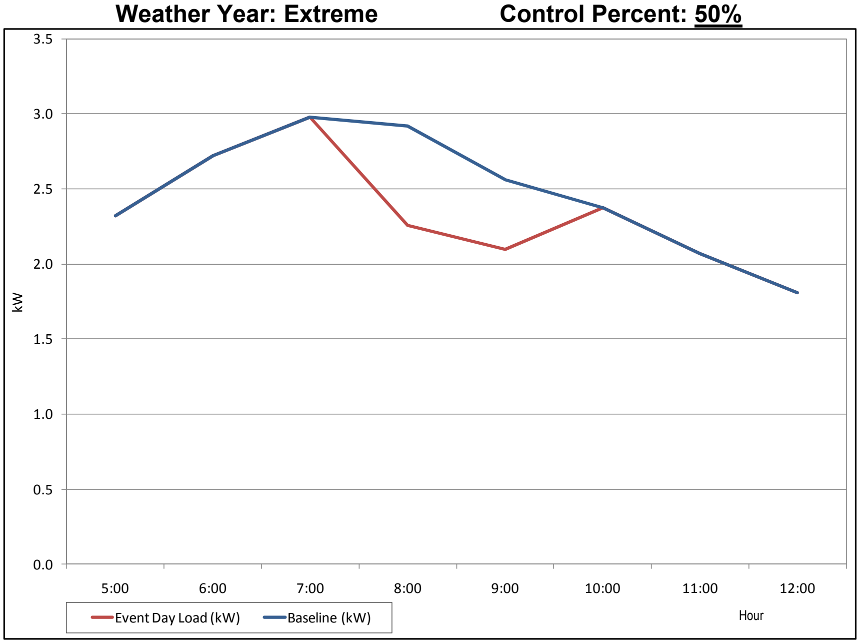
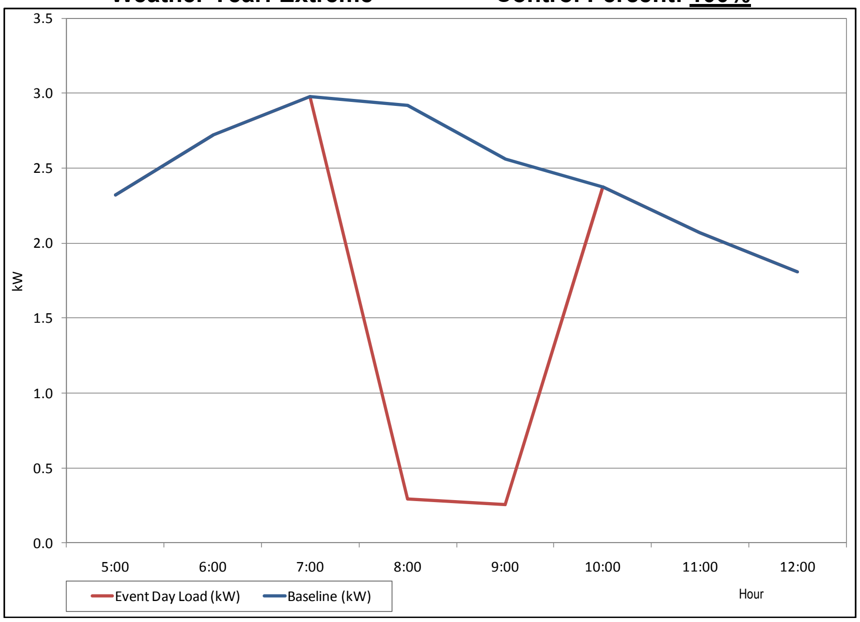


Figure 4-4: Auxiliary Strip Heat Load Impact Projection
Weather Year: Extreme **Control Percent: 100%**



4.3.3 Load Impact Adjustment Effect

Load Impact Adjustment is a factor applied to the load impact projection to account for rate of non-response.

There are two[2] choices for the load impact adjustment effect:

- "Non-Response Adjustment" reflects the percent of non-responsive units that was estimated with data collected in the 2009/2010 winter season – about 10 percent for strip heaters.
- "No Adjustment" represents a 0 percent non-response rate. This scenario is unattainable in actual program operation, but it is a useful gauge for comparison to other scenarios.

Table 4-3 shows an example of the effect of the load impact adjustment: the expected differences in load impacts for the coldest day in a typical year, with a 100 percent control.

[2] The summer program load impact projections have three load impact adjustments available – the two mentioned here, plus an "empirical factor", which accounts for deviations from "perfect" adaptive cycling in addition to non-response rate. Since adaptive cycling is not available in the winter program, this third load impact adjustment is not utilized.

Table 4-3: Auxiliary Strip Heat Load Impact Projections
Weather Year: Typical Control Percent: 100%

Hour	Non-Response (kW)	No Adjustment (kW)
7 to 8 AM	2.4	2.6
8 to 9 AM	2.0	2.2

4.3.4 Comparison of Auxiliary Strip Heat Load Impact Projections to Deemed Savings

As discussed in Section 2.1.3, the impact of load control on the auxiliary strip heating in central heat pumps is very dependent upon the cycling amount, or percent of time the units are controlled. A 100 percent cycling which does not allow the heat strips to operate at all during the load control period can provide significant load reduction during peak hours. However, a 50 percent load control cycling strategy appears to yield only minimal, if any, savings in PEC's Western region.

Table 4-4 includes the program design assumptions ("PEC Deemed Savings") regarding auxiliary strip heating impacts, and the estimated projections at 100 percent cycling between 7 and 9 AM on an extremely cold[3] winter peak day and a typically cold[4] winter peak day. These figures show that at this level of cycling, the program is estimated to exceed its deemed savings.

Table 4-4: Auxiliary Strip Heating -- Load Impact Projections – 100% Control

EnergyWise Auxiliary Strip Heating	PEC Deemed Savings	Load Impact Projections	
		Extreme Weather	Typical Weather
Peak kW Savings	1.0	2.6	2.2
Total kWh Energy Savings	0.9	5.2	4.4

Table 4-5 includes the program design assumptions regarding auxiliary strip heating impacts, and the estimated projections at 50 percent cycling between 7 and 9 AM on an extremely cold winter peak day and a typically cold winter peak day. These figures show that at this level of cycling, the program is estimated to fall short of its deemed savings.

[3] Minimum hourly temperature: 4°F
[4] Minimum hourly temperature: 9°F

Table 4-5: Auxiliary Strip Heating -- Load Impact Projections – 50% Control

EnergyWise Auxiliary Strip Heating	PEC Deemed Savings	Load Impact Projections	
		Extreme Weather	Typical Weather
Peak kW Savings	1.0	0.43	0.31
Total kWh Energy Savings	0.9	0.86	0.63

4.4 Water Heater Load Impact Projections

This section details the load impact projections that were estimated for the water heating component of PEC's EnergyWise winter program under different scenarios.

Based on the data collected during the 2009/2010 winter season, water heating loads are estimated to not be sensitive to outdoor temperature. This is due to the fact that water temperature does not change much in a given season. While water coming into a water heater may be warmer in the summer than in the winter, water temperature within the same winter season does not vary enough to cause a difference in water heating loads. As a result, water heating load on the coldest day in January is about the same as it would be on the warmest day in the same winter season, even though the difference in outdoor temperature between these two days can be substantial. The estimation of these load impact projections is based entirely on the hot water use schedule implicit in the interval data collected for this project. While number of occupants is clearly an important determinant of water heating load, it cannot be used explicitly in these load impact projections because occupancy data is not available to program administrators.

Load control of water heaters in the EnergyWise program is only performed at 100 percent cycling, which means the water heater is not allowed to operate at any time during the control event period. This reduces the load impact projections to two scenarios only: with and without the non-response rate of approximately 15 percent. These scenarios are described in Table 4-6, and illustrated in Figure 4-5 and Figure 4-6. The average load impact with non-response is 0.35 kW between the hours of 7 and 9 AM. The snapback in the hour following the event is almost double that of the average event load reduction.

Table 4-6: Water Heater Load Impact Projections (kW)
Control Percent: 100%

Hour	Non-Response	No Adjustment
7 to 8 AM	0.37	0.44
8 to 9 AM	0.31	0.37
9 to 10 AM	-0.57	-0.67
10 to 11 AM	-0.08	-0.09
11 to noon	-0.01	-0.02

Figure 4-5: Water Heater Load Impact Projections with Non-Response Rate = 15%
Control Percent: 100%

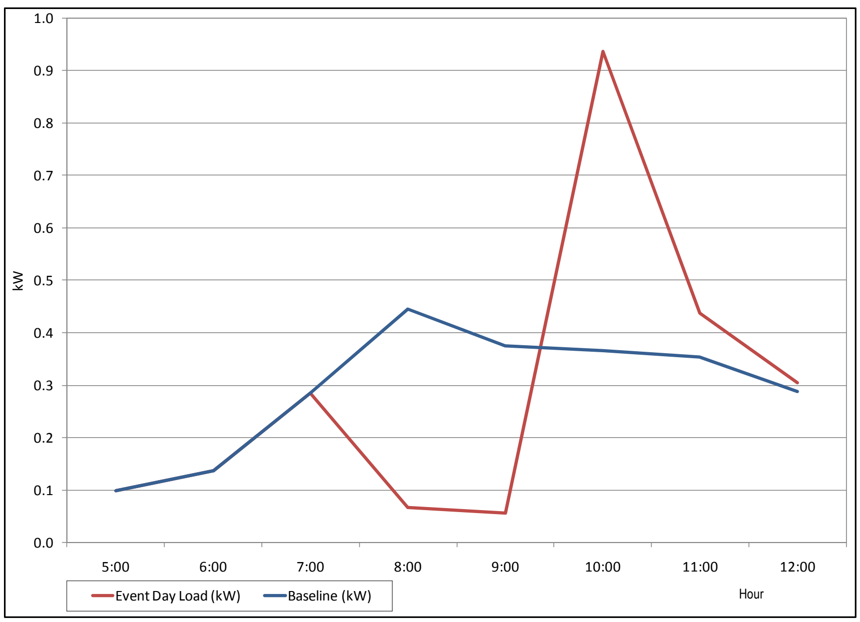
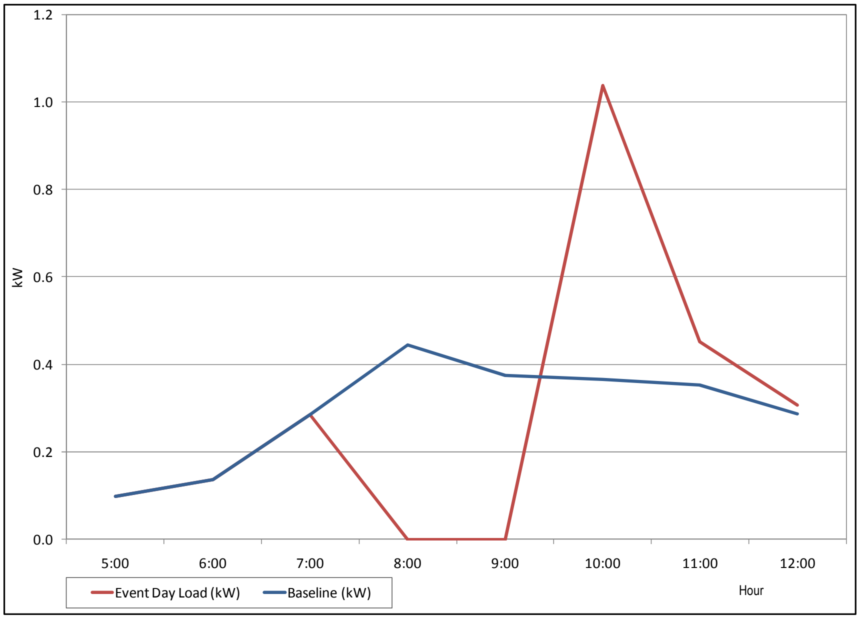


Figure 4-6: Water Heater Load Impact Projections with Non-Response Rate = 0%
Control Percent: 100%



4.4.1 Comparison of Water Heater Load Impact Projections to Deemed Savings

Table 4-7 includes the program design assumptions regarding water heater load impacts, and the corresponding projections at 100 percent cycling between 7 and 9 AM (i.e., without snapback) and from 7 to 10 AM (i.e., with snapback). These figures show that water heater impacts are below the program's deemed savings estimates.

Table 4-7: Water Heater -- Load Impact Projections
Control Percent: 100%

EnergyWise Water Heating	PEC Deemed Savings	Impact Evaluation Projected Savings		
		7 to 8 AM	8 to 9 AM	9 to 10 AM
Peak kW Savings	0.8	0.38	0.32	-0.57
Total kWh Energy Savings	0.9	0.70		-0.57

5. Recommendations

The measurement and verification study conducted in the winter of 2009/2010 was the first of two M&V efforts planned by PEC and provides valuable information that can be used to improve the future load impacts of PEC's EnergyWise winter program. This initial M&V effort identified several performance improving opportunities that will be further investigated in future program activities and M&V efforts. Because this M&V study was conducted shortly after program launch, the results are derived from a relatively small sample of early program adopters. The follow-up M&V that is planned for the winter of 2011/2012 should provide further data with which to make a comprehensive assessment of future load impacts.

1. **Increase the percent control for the strip heater program to 100 percent**. Fifty percent cycling proved to be a very mild level of cycling.

2. **Investigate options to reduce the level of snapback observed in water heating**. These may include a staggered release from direct load control, which would cause snapback to spread over several hours. However, it would also cause some program participants to be in control mode longer than others. The consequences of such release have to be explored carefully, and possibly paired with customer research.

3. **Monitor the rate of non-response observed in the winter program**. Due to the nature of these appliances and the mountain terrain in this region, it is unclear, based on the activity conducted to-date, if the winter program will achieve the low rates of non-response observed in the summer program.

4. **Conduct further M&V activities, with the following purposes:**

    a. **Understanding the load patterns and potential load impacts of program participants that are not first adopters**. There is substantial market research in the energy industry that proves that first adopters of a program such as EnergyWise tend to be different than those that join as the program matures. First adopters tend to be more focused on the environmental message of a program like this, and potentially more likely to tolerate discomfort.

    b. Investigating whether 100 percent cycling increases auxiliary strip heating snapback or not.

    c. Investigating whether any actions taken to reduce non-response rates and water heating snapback are successful.

Appendices

Appendix A: Methodology

This section describes the methodology employed in the load impacts measurement and verification (M&V) of the EnergyWise winter 2009/2010 season. The M&V effort included the following elements:

- Sample Design and Load Data Collection
- System Load and Temperature Data Analysis for the M&V Event Plan
- Load Data Preparation
- Load Data Modeling for 2009/2010 estimates: kW and kWh savings and snapback by hour for each M&V event conducted, at the participant level
- Weather Data Analysis for load impact projections
- Load Impact Projections for different temperature conditions and control strategies

Sample Design

The M&V original sample design goal was to produce a stratified sample and recruit 125 water heaters and 125 strip heaters for the winter M&V sample. The data available to KEMA in November (for program participation as of October) reflected total program enrollment of 204 water heaters and 130 strip heaters. These quantities did not support a sample design effort. In light of this, PEC and KEMA solicited all program participants to participate in the winter sample.

The logging equipment was installed between November 9 and November 23. There were 179 M&V sample loggers installed at 131 participating residences. Indoor temperature loggers were installed at 65 residences. The breakdown by end use is presented in Table A-2.

System Load and Temperature Data Analysis for M&V Event Plan

In order to accurately estimate load impacts, it is important to collect data on days during EnergyWise control events and during days with no control events that have similar weather and schedule conditions. Further, the number of comparable days without events has to be greater than the number of days with events. This is because the days without events are the basis to estimate the baseline load, which in turn determines the load impacts. A thorough analysis of weather and system load data was conducted prior to the start of the 2009/2010 winter season, with the objectives to determine (1) how many weekdays within certain temperature ranges could be expected, and (2) what temperature conditions are associated to Western region system peaks.

KEMA analyzed PEC system load data and Western region system load data from 2007 thru November of 2009. This data was used to investigate the relationship between outdoor temperature and system peaks in the Western region, and is well suited to determine the conditions in which EnergyWise may be activated in winter. The data received included hourly data for the PEC system as a whole, and for the Western region.

As part of the analysis performed for this M&V effort, KEMA also analyzed the system data for the “other regions”, calculated as the difference between the PEC system and the Western region. The analysis of the other regions conditions and system peaks was performed to provide perspective on the Western region regarding differences in sensitivity to cold weather and size of the system peaks.

PEC and KEMA agreed to use the NOAA data for the weather station of Asheville[5] to represent the Western region. KEMA examined the 50 days with the highest system peak demands in each of the three years (2007 to 2009). For these years:

- The annual system peak is consistently occurs in the winter for the Western region, and in the summer for the other regions.
- PEC’s system load data confirms that winter peaks are mostly driven by the residential sector: they occur too early in the day, which makes them consistent with the residential sector.
- In the Western region, 66 percent of the top 50 daily system peaks occurred in hours ending 8 and 9 AM, 6 percent occurred in hours ending 10 and 11 AM, and 28 percent occurred in hours ending 7 to 9 PM.

Historical Temperature Data Analysis and M&V Event Plan

KEMA analyzed hourly NOAA weather data for the Asheville weather station from January 1998 to June 2009 to determine the distribution of winter temperatures in the Western region and identify extreme and typical temperature patterns for the months of December thru March. This

[5] The NOAA weather stations utilized are ASHEVILLE (3812) for the Western region and RALEIGH/DURHAM (13722) for the “other regions.”

information was then used to plan winter of 2009/2010 M&V events under weather conditions that resembled those in which the winter EnergyWise program may be activated.

Planned events fell in two groups: (1) events in conditions similar to those expected when the EnergyWise program is expected to be activated, affecting M&V sample participants only, and (2) events in milder conditions, affecting all program participants, whether they were in the M&V sample or not. The objective of the latter was to determine if an event in milder conditions would elicit a response from program participants, in the form of calls to the Program's call center.

Table A-1 summarizes the following:

- Weather analysis performed prior to the start of the season.
- Weather tracking performed for the 2009/2010 winter season. A substantial part of the weather analysis was performed on a monthly basis but it is summarized here at a season level. Weather tracking during the M&V season was performed daily.
- Planned number of events, including "additional" events, which would be conducted only if the data collected for baseline estimation supported more events.
- Actual number of events conducted.

Table A-1 includes the following elements:

- The first column describes the percentiles of daily minimum temperature in the weather analysis period.
- The table's section entitled "Total (December-March)" includes the second thru the fifth columns. The second and third columns describe the minimum daily temperature range for these percentiles. For example: 50 percent of all days in this analysis period have minimum temperatures that are below 26^{o}F.
- The fourth column includes the average number of days in each temperature range observed during the analysis period. For example, the average number of days with temperatures between 26 and 31^{o}F is 30.
- The fifth column includes the number of days in each temperature range that were used in the M&V 2009/2010 load impact analysis. This is less than the actual number of days in each temperature range, because weekends and holidays are not expected to be EnergyWise operation days (except under exceptional system need), and are not employed in baseline estimation. For example, there were 22 days with temperatures

between 26 and 31°F that were used to estimate the load impacts presented in this report.

- The table's section entitled "Planned Number of Events" includes the sixth thru the tenth columns. Column 6 indicates the minimum number of M&V events to be conducted during the study season. All of these are morning events – conducted at the time of day in which the western region is most likely to experience its system peaks.
- Columns 7 thru 9 reflect additional events that would be conducted if there was enough data collected in each temperature range for baseline estimation and if other conditions in the Western region supported it. The events enumerated in these columns include evening peak events, and supplemental morning events. There were five days in January and February that met the weather conditions specified for these events. However, due to the severe weather experienced in the region at the time, PEC and KEMA decided to not run M&V events on these days to avoid potential distractions to Call Center and field staff.
- The table's section entitled "Actual Number of Events" includes columns 11 thru 13. This section summarizes the number of M&V events conducted during the study season. All of these were morning events.

Table A-1:
Planned and Executed Number of EnergyWise Winter M&V Events (2009/2010)

	Total Number of Days (December – March)				Planned Number of Events					Actual Number of Events		
Percentiles of Daily Minimum Temperature	Daily minimum temperature from	Daily minimum temperature to	Average number of days in 1998-2009 in this temperature range	Actual number of days in 2009/2010 that can be used in M&V analysis	Morning	Additional Morning (if sufficient baseline days)	Evening (if adequate temperature conditions are expected)	Additional Evening (if sufficient baseline days)	Total	Morning	Additional Morning	Total
100%	55	61		0								
99%	49	54	1	0								
95%	45	48	5	2								
90%	39	44	6	12								
75%	32	38	18	21	1				1	1		1
50%	26	31	30	22	1				1	1		1
25%	21	25	30	14	2	1	1	1	5	2	1	3
10%	18	20	18	5								
5%	12	17	6	6	2		1		3	2		2
1%	5	11	5	2								
0%	< 4	4		0								
TOTAL			**121**	**84**	**6**	**1**	**2**	**1**	**10**	**6**	**1**	**7**

Load Data Preparation

The load data for each sampled participant was individually analyzed prior to using it in the modeling effort. Data were screened for measurement errors or isolated readings that fall outside of the expected ranges.

Table A-2 reflects the number of installed loggers (Installed Sample Size), number of loggers that could be used in the load analysis and modeling (Final Sample Size), and the percent of the total population that is included in the sample (Percent of Program Appliances in the Final Sample).

The data collected for three of the strip heaters and 24 of the water heaters was discarded. In the case of the water heaters, a logging problem resulted in the metering of only one of two resistances.

Since EnergyWise had recently started operations at the time of this M&V project, the percent of EnergyWise program participants that are in the sample and produced interval load data that was used in this analysis is high: 36 percent of all strip heaters and 64 percent of all water heaters were successfully logged for this project.

The final number of logger installations and usable loggers is described in the following table.

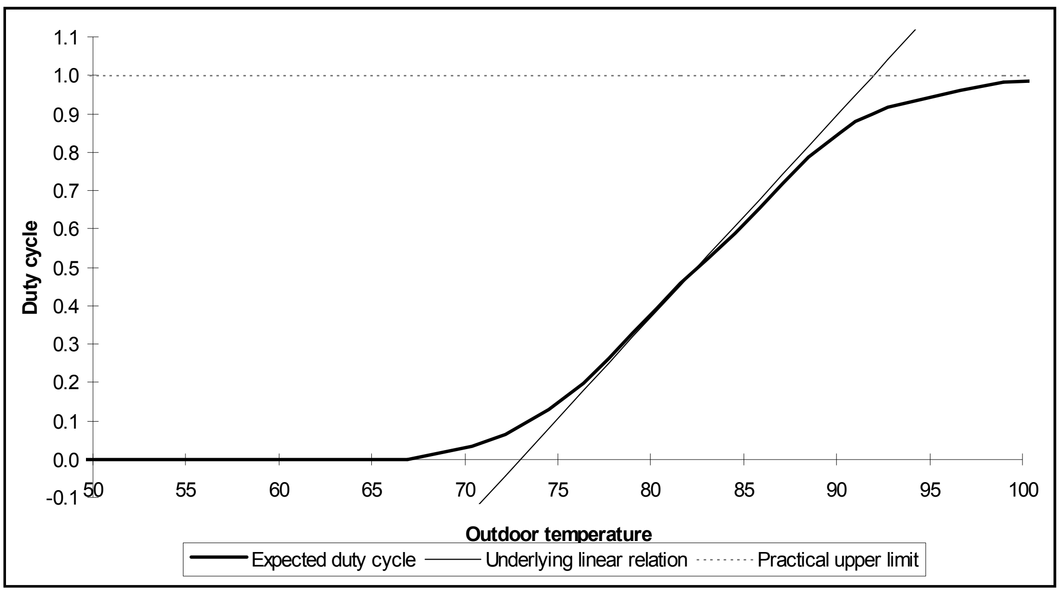
Table A-2:
EnergyWise 2009 Water Heater and Strip Heater Program Participants and M&V Sample Size

Equipment Controlled	Number of Appliances Enrolled in Program (as of 10/31/2009)	Installed Sample Size	Final Sample Size	Percent of Program Appliances in the Sample
Strip Heaters	204	76	73	36%
Water Heaters	130	103	79	61%
Total	**334**	**179**	**152**	**46%**

Model Specification

The Tobit duty cycle model is utilized for both water heater and strip heater load impact estimation. It is fitted individually to each sampled water heater or strip heater. The Tobit approach fits a simple linear functional form while taking into consideration that the percentage duty cycle data are censored at 0 and 1 (the duty cycle cannot be less than 0 percent or more than 100 percent.) Figure A-1 shows the underlying linear trend in relation to a smooth duty cycle curve. Estimating the linear model not in a Tobit framework will give results that do not account for the limits of connected load and can result in substantial overestimation.

Figure A-1: Duty Cycle Model Schematic



Linear models are specified separately for water heater and strip heater separately.

The strip heater model specification is:

$$L_{dh} = I_h + M_d + \beta_{1h} AVGTEMP_{dh} + \beta_{2h} AVGTEMP24_{dh} + \varepsilon_{dh}.$$

Where:

L_{dh}	= Duty cycle on day d hour h
I_h	= time of day indicator variables, at 30-minute interval
M_d	= Monthly indicator variables
$AVGTEMP_{dh}$	= Moving average hourly temperature of previous 4 hours
$AVGTEMP24_{dh}$	= Moving average hourly temperature of previous 24 hours
β_{1h}, β_{2h}	= Reference heating load coefficients determined by the regression
ε_{dh}	= Residual error

Outside temperature was not shown to have a strong effect on water heater use. Water heater use is mostly related to occupant schedules.

The underlying water heater model specification is:

$$L_{dh} = I_h + M_d + \varepsilon_{dh}.$$

Where:

L_{dh}	= Duty cycle on day d hour h
I_h	= time of day indicator variables, at 30-minute interval
M_d	= Monthly indicator variables
ε_{dh}	= Residual error

Both water heaters and strip heaters were found to have very low duty cycles. For example, an average strip heater in Raleigh area operates about 10 minutes per hour. Because of this, KEMA decided to use smaller (less than hourly) intervals in the load models. Thirty-minute intervals were used instead.

The primary driver of strip heater load is the temperature of the previous hours. Outdoor temperature has a lagged effect on house heating. Different combinations of lagged moving average temperature variables were tried in the model. The final model includes previous 4- and 24-hour moving average temperatures, indicating that a very cold day has an influence on the heating usage of the next day.

Different combinations of outdoor temperature were tried in the water heater model. However, all temperature variables tested were not statistically significant. This confirms that outside temperature does not play a significant role in water heater usage, and that water heater usage is closely related to occupant schedules. A water heater model that includes time-of-day and monthly effects produces results that are very close to the sample's actual average load.

The two models are used to produce the expected duty cycle of each unit in the sample. This estimated duty cycle is then multiplied by the unit's connected load to get model-estimated kW.

The connected load is the unit's electricity draw when the unit is running. This is equivalent to installed capacity – the unit will draw a kW amount within a narrow band when it is running, regardless of temperature or schedule. However, the temperature and the schedule – and in the case of program participants, the load curtailment event – will determine for how long it runs.

The final step in the modeling process is to estimate half-hour average kW across all sampled units.

Appendix B: Examples of Non-Response Rates

The following subsections provide examples of the visual inspection used to determine whether units were responsive or not. The graphs present one-minute load data between the hours of 6 AM and 1 PM.

Examples of Auxiliary Strip Heater Response Assessment

Figure B-1 illustrates a case where the effect of the control is clearly visible. An auxiliary strip heating unit on a central pump that has been running continuously since 7 AM clearly cycles on and off during the event hours, and then resumes continuous operation after the event ends.

Figure B-1: Example of auxiliary strip heat load where the effect of the EnergyWise control is clearly visible

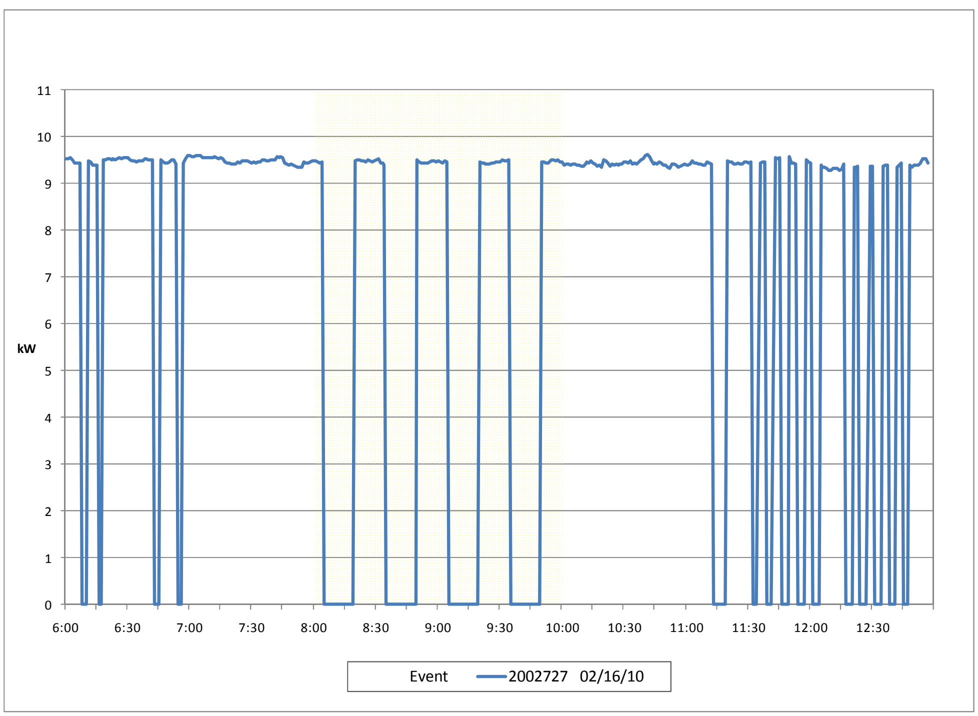


Figure B-2 corresponds to a unit for which we were not able to determine whether it was responding to control or not. Comparisons of event hours to the hours before and after the event, and to other weekdays surrounding the event days, show that the unit's use pattern is not easy to discern, and thus it is not possible to determine whether the unit was controlled or not.

Figure B-2: Example of auxiliary strip heat load where the effect of the EnergyWise control cannot be determined

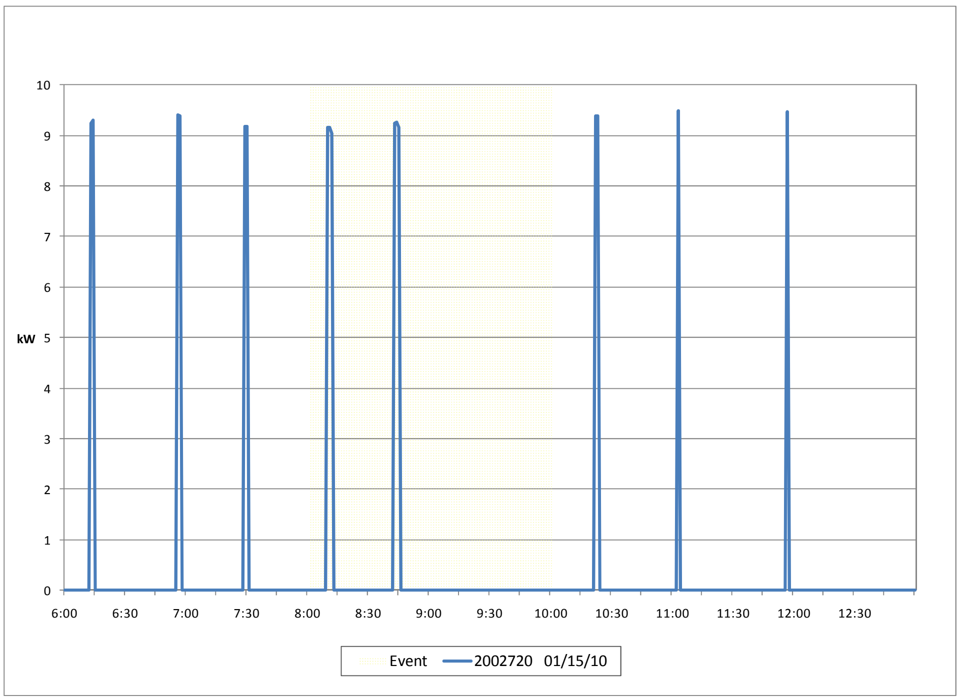
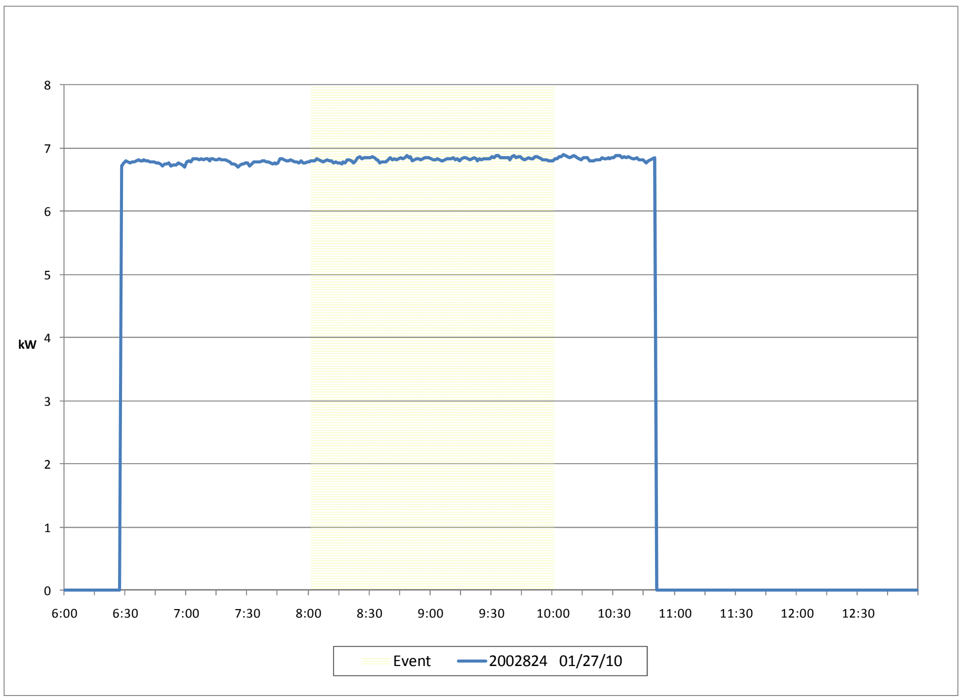


Figure B-3 corresponds to a strip heater that clearly did not respond to the control. A unit that has been running non-stop since approximately 6:30 continues to do so until 10:45 AM. This particular unit failed to respond to all events conducted, except for one, where its response status could not be determined.

Figure B-3: Example of auxiliary strip heat load where the effect of the EnergyWise control is clearly absent



Examples of Water Heater Response Assessment

Figure B-4 illustrates a case where the effect of the control is clearly visible. A water heater that has been cycling continuously prior to the event is off during the event hours, and resumes operation after the event ends. The water heater is continuously on for an hour after the event to compensate for the period in which it was off, and eventually resumes regular cycling.

Figure B-4: Example of water heater load where the effect of the EnergyWise control is clearly visible

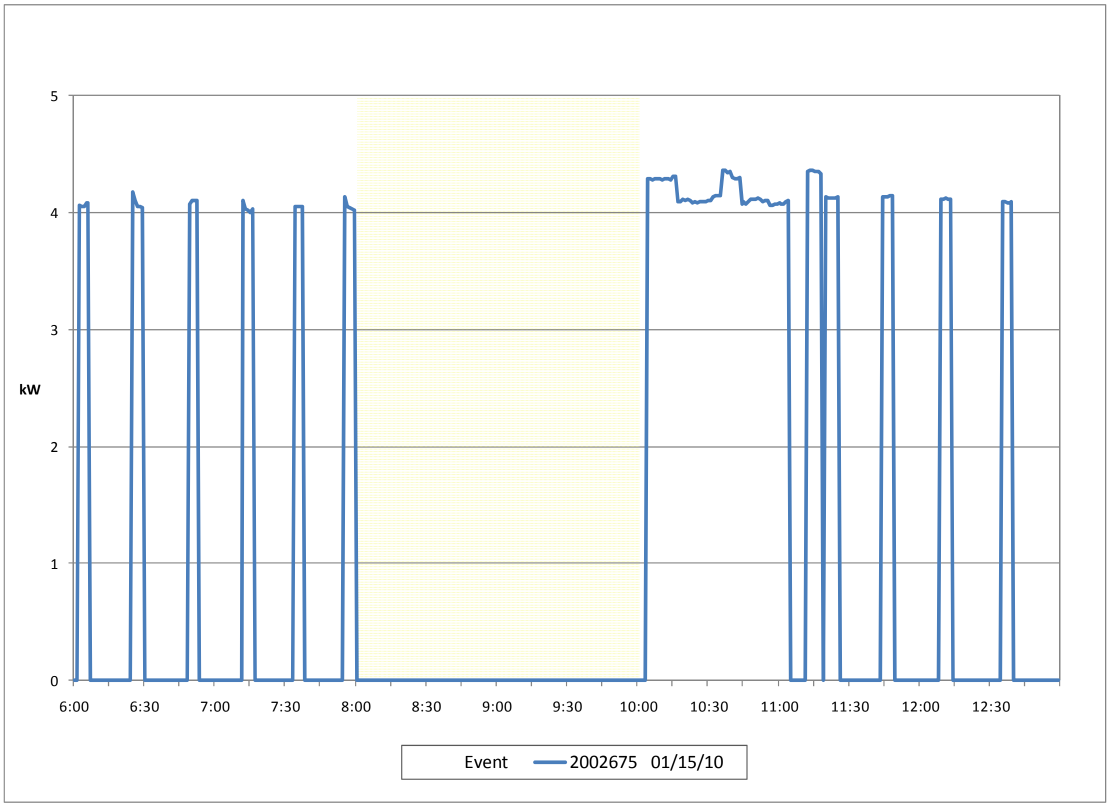


Figure B-5 corresponds to a unit for which we were not able to determine whether it was responding to control or not. The unit was off prior to the event, and continues to be off right after the event ends. It draws load for eight minutes only during the period between 6 AM and 1 PM. The response status of this unit was not determined for all events except one.

Figure B-5: Example of water heater load where the effect of the EnergyWise control cannot be determined

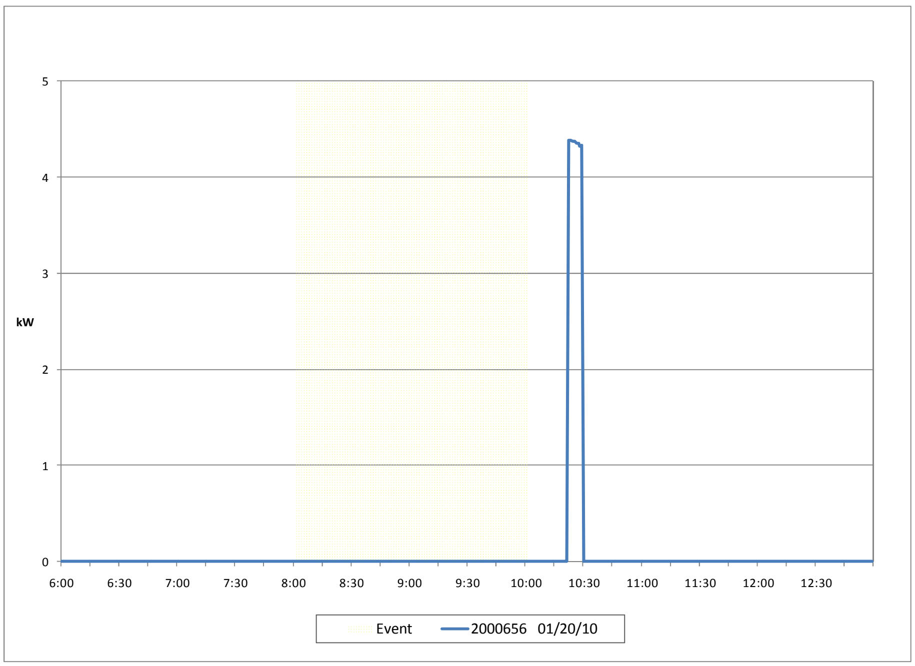


Figure B-6 corresponds to a water heater that clearly did not respond to the control. A unit that has been cycling prior to the event continues to do so during the event. Since water heaters are controlled at 100 percent, there should be no load during the event.

Figure B-6: Example of water heater load where the effect of the EnergyWise control is clearly absent